HANDBOUND
AT THE
UNIVERSITY OF
TORONTO PRESS

Digitized by the Internet Archive
in 2009 with funding from
Ontario Council of University Libraries

http://www.archive.org/details/memoirscaliforni01cali

MEMOIRS

OF THE

CALIFORNIA ACADEMY OF SCIENCES.

VOL. I. – 2

SAN FRANCISCO

1868. -1896

Q
11
C17
V.1-2

612962
4.7.55

CONTENTS OF VOLUME I.

I. A Catalogue of the Species of Mosses found up to the present time on the Northwest Coast of the United States, and especially in California ..... *By Leo Lesquereux.*

(Published January, 1868.)

II. The Natural System of Volcanic Rocks ..... *By Ferdinand, Baron Richthofen.*

(Published January, 1868.)

ERRATA.

Page 6, 1st line, for "Wusiaceæ" read "Weissiaceæ."
" 6, 9th line, from top for "Weisia" read "Weissia."
" 7, 21st " " " " "Breverianum" read "Brewerianum."
" 15, 16th " " " " "heterostychum" read "heterostichum."
" 26, 9th " " " " "thyphylla" read "ithyphylla."
" 32, 10th, 18th, 19th " " " " "Breverianum" read "Brewerianum."
" 34, 3d " " bottom for "Eurynchum" read "Eurhynchum."
" 37, 5th " " top " "commulatum" read "commutatum."
" 37, 10th " " " "Rhitidium" read "Rhytidium."

MEMOIRS

PRESENTED TO THE CALIFORNIA ACADEMY OF SCIENCES.

VOLUME I.

I. *A Catalogue of the Species of Mosses found, up to the present time, on the North-West Coast of the United States, and especially in California.*

By Leo Lesquereux.

[Presented Dec. 2d, 1867.]

PRELIMINARY NOTICE. This catalogue comprises all the species of Mosses found, up to the present time, so far as I know, on the western coast of North America, from the Mexican boundary to British Columbia. Most of the species are from California, gathered there by Dr. Bigelow, and Messrs. W. H. Brewer and H. N. Bolander of the State Geological Survey. It is to the last-named gentleman that the Bryology of the State of California is chiefly indebted. To render this list more complete, I have admitted into it the species collected by Dr. Lyall, in Oregon, on the Northwest Boundary Survey, along the 49th parallel, from the western base of the Rocky Mountains to Vancouver Island included.

I have not attempted, in this enumeration, to suggest any peculiar system of nomenclature or classification; but have merely followed what I considered the most natural grouping, copied from the "Bryologia Europæa," and from Schimper's Synopsis of European Mosses. New systems of classification are now originated in bryologic science, as it appears to me, for the mere satisfaction of their authors, and without the slightest advantage to science. Indeed, these new systems have had a most baneful influence on the study of this most interesting department of botanical science. A discussion of their merits—or rather, their demerits—will, especially in a catalogue like this, be useless.

Some species of mosses, considered as new and distinct by authors of high reputation, are included in this catalogue as mere varieties. The flora of California, in all its departments, is liable to great local varieties, according to the peculiar atmospheric and chemical conditions to which it is subjected. The more the phænerogamic flora of

that region is studied, the more the number of species is diminished. Having had access to a very large number of specimens—thanks to Mr. Bolander's zeal in collecting—I have been able to compare forms from different stations, and to see characters considered by others as indicating difference of species, blended together, sometimes even on the same specimen.

To prevent repetition of references, I will merely say that the species mentioned from Mr. Mitten, have been published in his Bryologia of the 49th Parallel of Latitude, in the *Proceedings of the Linn. Soc. of London, Bot., Vol. VIII*, —; the species from Hampe in a pamphlet, *Musci Californici Novi*, 1860; those of Muller, not included in his synopsis, in the *Bot. Zeitung, No.* 40; those of Sullivant in *the Reports of Lieut. A. W. Whipple's and Chs. Wilkes' U. S. Expeditions;* and those of myself in *the Transactions of the Amer. Philos. Soc. of Philadelphia, Vol.* 13. A few species given with short diagnoses in the *Musci Exsiccati Americani, Ed. 2d.*, by *Sullivant and Lesquereux*, are here copied from this work, which has been published in a limited number of copies, and which is not therefore accessible to every bryologist.

As this enumeration is intended as a representation of our actual knowledge of the Bryology of the west coast of the United States, I have carefully mentioned the habitat of the species, and the names of the botanists who have gathered them.

Columbus, O., 30th March, 1867.

CATALOGUE.

MUSCI.

SPHAGNEÆ.

SPHAGNUM, Dill.

1. **S. acutifolium,** Ehrh.
   Hab. Sierra Nevada; Upper Tuolumne Cañon; foot of Mt. Dana, 8,000 to 9,000 feet, *Bol.*

2. **S. fimbriatum,** Wills.
   Hab. by a brook, at about 11,000 feet on Mt. Brewer, *Brew.*

3. **S. rigidum,** Schp.
   Hab. Yosemite Valley, hillsides, in the spray of the Vernal Falls, *Bol.*

   Var. *B. compactum,* Schp.
   Hab. rivulets, foot of Mt. Dana, *Bol.*

4. **S. squarrulosum,** Lsqx Ms.
   S. squarrosum, var. B. Schp.
   Hab. head of William Lake, near Lassen's Peak, about 5,000 ft., *Brew.*

The first Sphagnum found in California. On this species Prof. Brewer remarks: "It forms a large bog, and is the only Sphagnum I have yet seen in the State "in more than 13,000 miles of peregrinations."

The true value of this species is still uncertain. In his remarkable *Mémoire pour servir à l'histoire des Sphaignes,* (1857) W. P. Schimper mentions it as possibly a small marked form of *S. squarrosum,* Pers., and in his *Synopsis Muscorum Europeorum,* (1860) he joins it to this last species as *var. B.* The far different facies, long, slender branches, similar to those of some forms of *Sphagnum cuspidatum,* Ehrh.; the longer, narrower leaves, also indicate a specific difference. By details of analysis, *S. squarrulosum* shows indeed in the cross-sections of the leaves the same kind of reticulation as *S. squarrosum,* viz: large, round, primary cells with intermediate, elongated, narrow oval ones. But this is the only affinity; and even the cells are narrower in *S. squarrulosum,* and accordingly the leaves are proportionally thinner. The nearest relative to this still uncertain species is *S. rigidum,* Schp. One of its varieties, from the Racoon Mts. of Alabama, with branch leaves contracted above the middle and the point reflexed, is

much like it, our species differing merely by more acute branch leaves and a broader reticulation of the stem leaves—differences of little importance. Therefore if *S. squarrulosum* should be united to any species as a variety, it would rather go with *S. rigidum*. But it is better to let the species stand as it is till its fruit is known, and it can be thus thoroughly studied. It is right to remark also that it was originally found in the bogs of the Jura Mountains, of Switzerland, where *S. squarrosum* has never been seen. For this species more generally inhabits the bogs and streams of primitive rocks, and not the limestone.

5. **S. subsecundum,** Nees & Hrnsch.

Hab. wet meadows, Mariposa Big Trees, *Bol.*

Var. B. *longifolium*, ramis attenuatis longioribus, foliis angustis lanceolatis, elongatis.

Hab. Mendocino City, swamps, *Bol.*

6. **S. auriculatum,** Schp.

Hab. in swamps, 8,000 to 9,000 ft., between forks of King's River, *Brew.* In pools, near Mendocino, *Bol.*

The form from Mendocino has a peculiar facies, which is not seen in any European specimens. The leaves are longer and narrower, the branches more slender and attenuated, similar to those of the floating large varieties of *S. cuspidatum*. But it has the lanceolate-pointed shape of the leaves, especially the loosely reticulated branch leaves, and the stem leaves with fibrillose stems filled with very numerous round small pores, a character ascribed by Schimper to this species only. The differences may be considered as mere local variations. In the California moss the auricles of the stem leaves are not more developed than they are generally in *S. subsecundum*.

7. **S. cymbifolium,** Ehrh.

Hab. swamps near Mendocino City, *Bol.*

PHASCACEÆ.

EPHEMERUM, Hampe.

8. **E. serratum,** Hampe.

Hab. on the ground in fields and meadows, Mission Dolores, *Bol.*

SPHERANGIUM, Schp.

9. **S. muticum,** Schp.

Hab. with the former, *Bol.*

This species has not yet been found, to my knowledge, in the Atlantic States, where it is represented by an intermediate form equally referable to both *S. muticum* and *S. triquetrum*, Schp. It is *S. triquetrum*, var. No. 31, of the Musci Exsicc. Amer., Ed. 2d.

PHASCUM, Schreb.

10. **P. cuspidatum,** Schreb.

Hab. with the former, *Bol.;* with var. *piliferum*, Fort Colville, *Lyall.*

11. **P. bryoides,** Dicks.

Var. B. *piliferum*, Schp. Synop.

Hab. south side of hills of Oakland, *Bol.*

A few specimens only were sent, mixed with *Anacalypta Starkeana* and *Weisia viridula.*

PLEURIDIUM, Brid.

12. **P. subulatum,** Brch. & Schp.

Hab. ditches and dry hills, San Rafael, *Bol.*

By the form of the capsule and of the leaves, the California moss is referable to *P. alternifolium*, Brch. and Schp. Even the two years' old plants bear slender innovating branches with short distant leaves, similar to the flagelliform branches of *P. alternifolium.* Yet, the inflorescence is that of *P. subulatum*, the anthers being free in the axils of the upper leaves.

BRUCHIA, Schwægr.

13. **B. Bolanderi,** spec. nov. Monoica, dense gregaria, cæspitulosa, pallide virescens. Caulis brevis, vix linearis, basi tantum radiculosus, simplex. Folia caulina remota, minuta, lanceolata ; comantia erecto-aperta lanceolata, brevi subulata, costa plana sub apice obscure et obtuse serrulato desinens, reti basilari quadrato-elongato, apiciali angustiore distincto ; folia perichætialia late ovata, amplectentia tubulosa, externa breviter acuminata, interna lanceolato-subulato erecta, caulinis duplo longiora, reti laxiore. Capsula in pedicello robusto, semipollicari subflexuoso erecta vel subobliqua, e collo elongato pallide viridi oblonga angusta, virescens, in rostrum rectum pallidumque producta ; calyptra tertiam partem capsulæ obtegens, basi laciniata. Inflorescentia vere monoica sed primo intuitu dioica videtur, caule primario repente, radiculoso masculas, femineasque gemmas radiculosas gestante. Flores masculi crassiores, foliis perigonialibus internis brunneis, ovato lanceolatis acutis, obsolete nervosis.

Hab. near Big Tree Grove, Mariposa ; Westfall's Meadow, 8,000 ft. *Bol.*

It is not easy to separate this species from *Vogesiaca*, Schw. The inflorescence is the same ; at least, male and female buds bear in their position the same relation. The long pedicel, the form and color of the capsule, are also similar. The difference is essentially in the shorter stems, shorter leaves, the shorter beak, and especially the longer collum of the capsule. The pedicel is thicker than in the European species, slightly flexuous when dry, straight when moistened. The color of the plants is of a pleasant pale green.

WUSIACEÆ.

GYMNOSTOMUM, Brch. and Schp.

14. **G. calcareum,** Nees and Hrnsch.
Var. *perpusillum*, Sulliv. Whipple's Exped. p. 185.
Hab. on clayey soil, near San Francisco, *Big.*

15. **G. curvirostrum,** Hedw.
Hab. on wet rocks, Leroux Springs, base of San Francisco Mts.; Mogollon Ridge, *Big.*

WEISA, Hedw.

16. **W. viridula,** Brid.
Hab. on the ground, at and around San Francisco, *Bol.*, *Big.*
Var. capsulis longioribus, ovato-cilindricis, regulariter plicato-striatis, viridibus.
Hab. on the ground, San Francisco, *Bol.*

17. **W. cirrhata,** Hedw.
Hab. region of the Redwoods, common, especially on burnt and decayed wood; Big Trees, etc., *Bol.*, *Big.*; Vancouver Island, *Lyall*; N. W. America, *Douglas.*

18. **W. crispula,** Hedw.
Hab. Galton Mts., near Fort Colville, *Lyall.*

DICRANUM, Auct.

§ 1. CYNODONTIUM, Schp. Syn.

19. **D. polycarpum,** Ehrh.
Hab. Cascade Mts., Lyall.

20. **D. virens,** Hedw.
Var. G. *serratum.* Schp. syn.
Hab. Tuolumne Cañon and Mono Pass, 9,000 ft., borders of snow-water streams, *Bol.*; Galton Mts., *Lyall*, alt. 6,000 to 7,000 ft.

21. **D. crispum,** Hedw.
Hab. Galton Mts., *Lyall.*

§ 2. DICRANELLA, Schp.

22. **D. varium,** Hedw.
Hab. on perpendicular sandstone rocks, watered by springs, near the bay of San Francisco, *Bol.*

23. **D. subulatum,** Hedw.
Hab. foot of Mt. Dana, 8,000 to 10,000 ft., borders of ditches and streamlets, *Bol.;* Galton Mts., *Lyall.*

24. **D. heteromallum,** Hedw.
Hab. slopes of a ditch cut through a bog, edge of the redwoods near Big River City, *Bol.;* Cascade Mts., *Lyall.*

§ 3. DICRANUM, Schp.

25. **D. strictum,** Schl.
Hab. coniferous trees, Devil's Cañon, Forest Hill, *Bol.;* Fort Colville, *Lyall.*

26. **D. albicans,** Brch. and Schp.
Hab. N. W. America, *Douglas.*

27. **D. fuscescens,** Turn.
Hab. Redwoods, Bol.; Spokane River, Oregon, *Wilkes' U. S. Exp.;* Galton Mts., *Lyall.*

28. **D. scoparium,** Lin.
Hab. Oregon, *Wilkes' Exp.;* and a var. foliis vix denticulatis, in California? *Bol.*

29. **D. palustre,** Lapyl.
Hab. Pend' Oreille, *Lyall;* Vancouver Island, Wood. *Mr. Bolander* has sent it from Eureka, Humboldt County.
Var. foliis angustioribus, lævibus, falcato-secundis, areolatione longiori. *D. Breverianum,* Lsqx. in litter.
Hab. Deep Cañon, Klamath River, *Brew.*

This variety is remarkable enough to be considered a proper species. Besides the characters indicated above, it differs from *D. palustre* by its shorter stems, its narrow, not at all, or scarcely undulate leaves, its more incurved, and more slender, and longer capsule, the great quantity of male plants intermixed in the cæspites. The male plants are slightly more slender than the fertile ones; the flowers large, terminal, or lateral by innovations; the perigonial leaves broadly ovate, narrowed into a pretty long point and nerved.

30. **D. majus,** Schwægr.
Hab. Fort Discovery, Oregon, *Wilkes' U. S. Exped.*

FISSIDENS, Hedw.

31. **F. limbatus,** Sulliv.
Hab. on shaded ground, near Oakland; common around San Francisco, *Bol., Big.*

32. **F. ventricosus,** spec. nov. Monoicus, robustus, laxe lateque cæspitosus, cæspitibus nigricantibus, innovationibus junioribus apice tantum atro-viridibus. Caulis ultra pollicaris, e basi divisus, divisionibus simplicibus vel parce ramosis. Folia multijuga, conferta, erecto-aperta, cultriformia, duplicatura di-

latata ad mediam laminam verticalem procedente, margine crasso, gibboso, plerumque cum costa crassa in apiculum muticum confluente, raro sub apice cum costa evanido. Areolatio ovato-quadrata vel irregulariter polygona, minuta. Flores utriusque sexus terminales; folia perigonalia late ovata, sub lamina verticali apiculiformi irregulariter dissecta; folia perichætialia conformia. Capsula in pedicello brevissimo, vix exserta, erecta, obovata, in pedicello attenuata, obscure viridis. Peristomii dentes erecti latiores; sporæ ovales magnæ.

Hab. on submerged rocks, Mendocino City, *Bol.*

By the ventricose or enlarged duplicature of its leaves, this species resembles *F. rufulus*, Brch. & Schp. In our species the leaves are more obtuse, and generally entirely surrounded by a thick margin like those of *F. rivularis* of the same authors. It is only in the upper leaves of new branches that the leaves appear similar to those of *F. rufulus*. The division of the stems is generally from near the base and dichotomous, sometimes the primary divisions being divided again near the top in short branches. The axils of all the leaves bear tufts of radicles. The specimens sent to me had but one capsule, already deoperculate.

33. **F. adiantoides**, Hedw.
Hab. Fort Colville, *Lyall.*

33*a*. **F. grandifrons,** Brid.
Hab. sea-shore, Mattole District, Humboldt Co.; rocks over which spring water flows constantly, *Bol.*, June, 1867.

POTTIACEÆ.

POTTIA, Ehrh.

34. **P. subsessilis,** Brch. & Schp.
Hab. Los Angeles, *Big.*

35. **P. cavifolia,** Ehrh.
Hab. Fort Colville, *Lyall.*

36. **P. minutula,** Brch. & Schp.
Hab. Los Angeles, *Big.*

37. **P. Heimii,** Hedw.
Hab. ditches near the Soda Springs, alt. 9,000 ft., *Bol.*

ANACALYPTA, Rochl.

38. **A. Starkeana,** Nees & Hrnsch.
Hab. Mission Dolores, Oakland, etc., on clayey ground, *Bol.*

DIDYMODON, Hedw.

39. **D. rubellus,** Brch. & Schp.
Hab. Tuolumne Cañon, near Soda Springs, 9,000 ft.; foot of Mt. Dana, *Bol.*

DISTICHIUM, Brch. & Schp.

40. **D. capillaceum,** Brch. & Schp.
Hab. on shelving rocks, between Vernal and Nevada Falls, Yosemite Valley, *Bol.*, rare; Cascade Mts., *Lyall.*

41. **D. inclinatum,** Hedw.
Hab. Soda Springs, *Bol.*

CERATODON, Brid.

42. **C. purpureus,** Brid.
Hab. California, common, *Bol.*, *Brew.*, *Big.*; spray of Nevada Falls on rocks, *Bol.*; Vancouver Island, *Lyall.*
Var. *B. xanthopus,* Sulliv. & Lsqx.
Hab. on *Sequoia sempervirens,* extremely common; also, Big Trees, *Bol.*, *Big.*

LEPTOTRICHUM, Hampe.

43. **L. Schimperi,** Spec. nov. Monoicum, subcæspitosum, subsimplex, humile lutescente-viride. Folia patentia, flexuosa, vel falcato-secunda, e basi ovata, lanceolata, subulata, valde elongata, angusta, apice tantum subdenticulata, costa tenui vix totam subulam occupante percursa. Perichætii elongati folia late amplectentia, interna tubulosa, in subulam longiorem attenuata. Capsula in pedicello vix ultra pollicari lutescente, robusta, erecta, ovato-cylindrica brunnea, operculo elongato conico recto vel subobliquo. Peristomii dentes in membrana basilari lata fugaci pulcherrime aurantiaca vel rubella, gracillimi, pallide lutei filiformes, læves, versus basim unocrure diviso tripartiti vel trabeculati. Annulus latior vix mediam partem membranæ attinens. Sporæ maximæ.
Hab. Coast Range, Mendocino, *Bol.*

This species much resembles *L. pallidum,* Hmp. But, besides the difference in the peristome, it is easily distinguished by its green color—the shorter, broader capsule borne on a shorter, thicker pedicel, having a longer, dark-red operculum. The leaves, also, of our species are much longer; their basilar reticulation larger, etc. The male flowers are gemmiform, axillary, and their leaves large, ovate, short, lanceolate, obtuse.

44. **L. flexicaule,** Schwægr.
Hab. Cascade Mts., *Lyall.*

TRICHOSTOMUM, Hedw.

45. **T. rigidulum,** Smith.
Hab. on rocks subject to overflow on Russian River, opposite Ukiah, *Bol.;* Vancouver Island, *Lyall.*

46. **T tophaceum,** Brid.
Hab. limestone rocks, constantly watered by a spring, Ukiah City; Fort Point, etc., *Bol.;* Cajon Pass, *Big.*

47. **T. anomalum,** Schp.
T. corniculatum, Wahl.
Hab. Oakland Cañon, *Bol.;* a few sterile stems mixed with *Hypnum leuconeurum;* Vancouver Island, *Lyall;* California, *Coulter.*

48. **T. flexipes,** Brch. & Schp.
T. crassinerve, Hmp. Musc. Calif.
Hab. in shaded grounds and decayed trunks, *Bol.*, *Big.*, *Bauer;* near San Rafael, and also in the mountains of the Coast Range, Mendocino, *Bol.*

DESMATODON, Brid.

49. **D. Californicus,** Spec. nov.
D. nervosus, var. B. *edentulus,* Sulliv. & Lsqx., Musc. Exsicc. Amer., 2d Ed., No. 121.
D. nervoso proximus, differt: caule breviore, foliis confertis, arctius imbricatis, brevi-acutis, vel nervo sub apice evanido obtusis, nervo medio inflato latiori, peristomii dentibus albidis, capsulo annulato.
Hab. on decayed ground and old walls of clay, (adobe) San Francisco, *Bol.*

Though the differences between both species are slight, the presence of an annulus, the broader, more inflated costa of the shorter generally obtuse leaves, appear the specific characters of the California moss.

50. **D. latifolius,** Hedw.
Hab. slopes of Tuolumne Cañon, *Bol.*

Var. *B. muticus,* Brch. & Schp.
Hab. Mt. Dana, 11,000 to 11,500 feet; Tuolumne Cañon, *Bol.;* Silver Valley, on exposed soil, 8,000 to 9,000 feet, *Brew.;* common in the mountains along water courses, Cascade Mountains, *Lyall.*

51. **D. systilius,** Brch. & Schp.
Hab. foot of Mt. Dana, *Bol.*

52. **D. Guepini,** Brch. & Schp.
Hab. on the ground, bank of a run, Oakland, *Bol.*

BARBULA, Hedw.

53. **B. membranifolia,** Hook.
Hab. dry ravines on William's Fork of the Great Colorado, *Big.*

54. **B. chloronotus,** Schultz.
Hab. same as the last, *Big.*

55. **B. fallax.** Hedw.
Hab. Cajon Pass, Sierra Nevada; also, near San Francisco, *Big.*

56. **B. subfallax,** Muller, Bot. Zeit. No. 40, p. 338.
Hab. San José Valley, *Bauer.*

57. **B. semitorta,** Sulliv., Whipple's Rep.
Hab. California, *Big.*

58. **B. brachyphylla,** Sulliv., ibid.
Hab. California, *Big.*

59. **B. artocarpa,** Lesqx.
Hab. Redwood Hills, Coast Range, Ukiah, etc., *Bol.*

60. **B. vinealis,** Brid.
Hab. near San Francisco, on the ground and stones, *Bol., Big.*

61. **B. rubiginosa,** Mitt.
Hab. N. W. America, *Douglas.*

62. **B. insulana?** De Not.
Hab. California, *Beechy.*

A remarkable form, perhaps referable to this species, has been collected by Mr. Bolander, on gravelly soil, near the Big Trees. It is subcæspitose, with a robust stem branching by innovations generally in two, opposite, from one-half to one-inch long. Its color is brownish yellow; the leaves when dry are appressed or slightly tortuous, open-erect by humidity, loosely imbricated, ovate lanceolate, very entire, revolute on the borders, with a strong excurrent nerve-forming point; the basilar reticulation is equilateral, elongated, pellucid; in the upper part of the leaves, the areolæ are opaque, minute and minutely papillose. The capsule borne on a short, straight, reddish pedicel of half an inch long, is large, oblong, of a reddish color, with an erect pointed operculum half the length of the capsule. The teeth of the peristome are red, twice twisted on a short membrane; the annulus is double, pellucid or white; the male flowers terminal and thick. This form is more robust than any other of the section of the *Vinealis*, and is easily distinguished by its appressed, scarcely twisted leaves, its thick, brown, reddish capsule on a proportionally short pedicel. The form and areolation of the leaves are like those of *B. vinealis;* but the peristome is twisted twice and dark red. The forms of this section of *Barbula* found in California are so numerous, that it will be necessary to reduce them to a few species, or to make a monograph of them, embracing more than one dozen species. I have only mentioned in this catalogue the most marked forms.

63. **B. flexifolia,** Hmp.
Hab. on sandy ground and boulders near the coast, San Francisco, *Bol.*, *Bauer.*

64. **B. virescens,** Lesqx.
Hab. same as the former, *Bol.*

65. **B. convoluta,** Hedw.
Hab. gardens in San Francisco ; burnt logs, Ukiah, *Bol.;* Oakland, *Big.*

66. **B. cuneifolia,** Brid.
Hab. clay soil, Oakland, *Bol.*

67. **B. Wahliana,** Schultz.
Hab. Cajon Pass, Sierra Nevada, *Big.;* Mt. Diablo, *Bol.*

68. **B. Bolanderi,** Lesqx.
Hab. on rocks, near San Francisco, *Bol.*

69. **B. amplexa,** Lesqx.
Hab. on sandstone around springs, in water, *Bol.*

70. **B. marginata,** Bryol. Eur.
Hab. on rocks near San Francisco, mixed with *B. flexifolia*, *Bol.;* on dry rocks, *Big.*

71. **B. brevipes,** Spec. nov. Dioica, gregaria vel cæspitulosa. Caulis brevissimus, simplex. Folia in comam conferta, lingulata, vel oblongo-cuneiformia obtusa margine revoluta, superne concavo-carinata, costa in pilum sublæve exeunte instructa, reticulatione basilari laxa, pellucida, quadrato-elongata, apicem versus compacta obscura irregulariter rotundata, chlorophillosa, papillosa. Capsula in pedicello longiori elongata, cylindrica, gracilis, subincurva, operculo longe conico obtusiusculo. Peristomii dentes arcte convoluti, sanguinei, in membrana longa quadrato-tessellata suffulti. Flos masculus in planta graciliori terminalis foliis perigonialibus brevibus-latioribusque.
Hab. on mud walls, Mission Dolores, in mats one inch in diameter or more ; divide of the Russian River, *Bol.*

This species is similar in appearance to *Barbula marginata,* but widely different in its non-marginate leaves, and its capsule and peristome, which are syntrichial.

72. **B. subulata,** Lin.
Hab. Big Tree grove, *Bol.;* dry ravines on Big William's Fork of the Rio Colorado, *Big.*

73. **B. inermis,** Brch.
Hab. base of mountains west of the Rio Colorado, *Big.* Sent also by Bolander without label.

74. **B. lævipila,** Brid.
Hab. railroad levees, Sacramento, *Bol.;* Vancouver Island, *Lyall.*

75. **B. latifolia,** Brid.
Hab. on *Alnus viridis,* borders of a creek near San Rafael, *Bol.*

76. **B. ruralis,** Hedw.

Hab. on rocks and trunks of trees from the plains to the mountains, very common, *Bol.*, *Big.*, *Brew.*, *Lyall.*

Var. *gigantea*, caule elongato, foliis e basi squarroso reflexis; areolatione papillosa, papillis elongatis, furcatis; costa dorso spinuloso-rugosa.

Hab. on moist rocks, Yosemite Valley, *Bol.*

77. **B. Muelleri,** Brch.

Hab. same as the former, especially common in the plain, *Big.*, *Bol.*, *Brew.*, *Lyall.*

GRIMMIACEÆ.

GRIMMIA, Ehrh.

78. **G. Scouleri,** C. Mull.

Scouleria aquatica, Hook.

Hab. on granite rocks in Merced River, at Clark's, near the Big Trees, sterile, *Bol.;* in Columbia River, near Fort Colville, *Lyall.*

79. **G. conferta,** Funk.

Hab. on metamorphic rocks, Mt. Diablo, *Bol.;* rocks in cañons near Green Valley, *Brew.*

80. **G. apocarpa,** Hedw.

Hab. on rocks, Yosemite Valley, *Bol.;* crossing of the Colorado, on rocks, *Big.;* N. W. America, *Lyall*, *Douglas.*

Var. *rivularis*, Brch. & Schp.

Hab. on wet rocks, Yosemite Valley, *Bol.*

81. **G. pulvinata,** Smith.

Hab. on metamorphic limestone-boulders, near Russian River, Ukiah; around Clear Lake, *Bol.;* rocks on Bill William's Fork, *Big.;* Fort Colville, *Lyall.*

82. **G. contorta,** Wahl.

G. uncinnata, Kaulf.

Hab. Big Tree grove, *Bol.*

I have received one specimen only with deoperculate capsule. The form of the leaves, their reticulation, the black color of the plants, and the small, slightly inclined capsule, mark the identity of this species.

83. **G. Muhlenbeckii,** Schp.

Hab. on a rock, specimen from Mt. Dana, 11,500 feet, *Bol.*

84. **G. trichophylla,** Grev.

Hab. on rocks, Redwood hills, common in California, *Bol.*, *Big.;* Vancouver Island, *Lyall.*

85. **G. ancistrodes,** Dur. & Mont.

Hab. on rocks, Dardanelles Cañon, *Bol.*

It agrees in every point with Muller's description of this species.

86. **G. Californica,** Sulliv.

Hab. on rocks, San Rafael, and around San Francisco, common, *Bol.*, *Big.*

Var. foliis caulinis obtusiusculis vel acutis, epiliferis, capsula subglobosa, operculo longiore.

Hab. same as the normal form, *Bol.*

87. **G. hamulosa,** Spec. nov. Dioica, irregulariter laxe pulvinata, nigricans. Caulis dichotome et innovante ramosus, subfasciculatim foliosus. Folia sicca homomallo-falcata, madefacta erecta hamuloso-incurvata, subhomomalla, laxe irregulariter imbricata, anguste lanceolato-subulata, apice plano obtusiuscula, carinato-concava, margine plana vel vix revoluta, nervo valido sub apice evanido intructa, reti basilari quadrato elongato, superiori irregulariter quadrato. Folia perichætialia longiora, longius acuminato-subulata. Theca in pedicello laterali medio curvulo, emersa, ovalis, lævis, pachydermis, brunnea, operculo conico brevi; peristomii dentes breviores, lacerati vel perforato divisi, annulo nullo.

Hab. gravelly soil, Mt. Dana, 10,000 ft., *Bol.*

It resembles *G. contorta*, Wahl., but is very distinct indeed by the hamulose and homomallous leaves, with long, subulate, opaque points; by the large emerged capsule, the curved pedicel, the absence of an annulus, etc.

88. **G. leucophæa,** Grev.

Hab. metamorphic rocks, Dardanelles Cañon, *Bol.;* Fort Colville, *Lyall.*

89. **G. montana,** Brch. & Schp.

Hab. on rocks from the plain to the mountains; boulders near San Francisco, Mt. Diablo, Mono Pass, 7,000 to 8,000 ft., *Bol.*

90. **G. alpestris,** Schl.

Hab. Fort Colville, and Pend' Oreille, *Lyall.*

RACOMITRIUM, Brid.

91. **R. patens,** Dicks.

Hab. between Fort Colville and the Rocky Mts., *Lyall.*

92. **R. aciculare,** Brid.

Hab. on granite rocks above the Yosemite Valley, *Brew.*

93. **R. depressum,** Spec. nov. Longe, lateque cæspitosum, depressum, fusco lutescens. Caulis elongatus, 4–5 pollicaris, parce dichotome ramosus, laxe foliosus. Folia siccitate appresssa, humiditate erecta, aperta, homomalla, e basi late ovata, dilatato-semiauriculata decurrente, lanceolata, obtusa nervo lato planiusculo sub apice evanido instructa, concavo-carinata, margine medio revoluta, superne reflexa, apice denticulis remotis irregularibus instructa, quandoque integra, retis alaribus quadratis vel equilateralibus latis, plus

minus ve granulosis, fuscis, basilaribus subtuberculoso linearibus continuis, superioribus ovato rotundatis. Capsula in pedicello brevi innovationibus duplo longioribus immersa, e basi brevicolla subcylindrica; peristomii dentes irregulariter tripartiti, raro bifidi, cruribus inæqualibus vel liberis, vel cohærentibus pertusis, lævibus.

Hab. falls of the Yosemite Valley, *Bol.*

This species, remarkable for its large size, is intermediate between *R. aciculare* and *R. protensum*, Brid. Its color is the same as that of var. *cataractarum* of the last, but the leaves turned to one side, even in the dry state, are larger, broader, and more obtuse, mostly denticulate, like those of *R. aciculare*, and nearly with the same areolation. The decurrent base of the leaves is slightly enlarged in a narrow auricle whose reticulation is particularly broad, resembling that of a *Dicranum*. The capsule, open at the mouth, is nearly exactly cylindrical, and sometimes slightly curved. The teeth of the peristome, generally tripartite near the base, are irregular, like those of *R. protensum*, but narrow, smooth, with well marked articulations.

94. **R. heterostychum,** Brid.

Hab. Fort Colville, *Lyall.*

95. **R. lanuginosum,** Brid.

Hab. Vancouver's Island, *Wood;* Mt. Rainier, Oregon, *U. S. Exp. Wilkes.*

96. **R. canescens,** Brid.

Hab. Vancouver's Island, *Lyall.*

Var. foliis pellucidis acuminatis, angustius reticulatis, vix papillosis.

Hab. on shaded rocks near the Paper Mill, Marin Co., *Bol.*

HEDWIGIA, Ehrh.

97. **H. ciliata,** Ehrh.

Hab. on stumps of *Sequoia sempervirens, Bol.;* on rocky cliffs of Bill Williams' Fork, *Big.;* British Columbia, *Lyall.*

BRAUNIA, Brch. & Schp.

98. **B. Californica,** Lesqx.

Hedwigia pilifera, Mitt.

Hab. on metamorphic rocks on low mountains; Mt. Diablo to 3,000 ft., very common and variable, *Bol.;* Vancouver's Island, *Lyall.*

In my description of this species, I have omitted to mention a few characters which, apparently important when one specimen only is considered, are, on the whole, local peculiarities or varieties only. This omission has led Mr. Mitten to suppose that his *Hedwigia pilifera* of Vancouver Island might be a different species, its capsule being plicate and the branches not inflated at the top. The capsule is indeed sometimes plicate, but generally smooth, at least when moistened. On rocks exposed to the sun, the branches of this species are longer and thickened at the top, and the perichætial

leaves are much shorter. When growing in the shade, the appearance of the plants is different, the leaves being longer and not appressed closely to the stem, etc. But the true specific characters of this species, as they are given in the description, are recognizable in every form.

PTYCHOMITRIUM, Brch. & Schp.

99. **P. Gardneri,** Spec. nov. Ramificatione, habitu, formaque foliorum, P. *polyphyllo*, Brch. & Schp., simillimum, differt: foliis brevioribus, latioribus, siccitate tortilibus vel cirrhatis, reflexis humiditate, margine argutius serratis, retis basilaribus longioribus, superioribus cellulis quadratis confertioribus; capsula in pedicello breviori, pallide ferruginea longiori, operculo longiori rubello persistente, margine minus crenulato; annulo angustiori revolubili; peristomii dentibus crassioribus, atro-sanguineis, ad basim plerumque trifidis; calyptra lævi.

Hab. on rocks, Dardanelles Cañon, Forest Hill, *Bol.*

The large size of this moss separates it at first sight from the European species. The male flowers are rarely axillary, generally two to four at the base of the vaginule within the perichætium. Its color is dark green.

ORTHOTRICHEÆ.

ZYGODON, Brch. & Schp.

100. **Z. Lapponicus,** Brch. & Schp.
Hab. spray of the Nevada Falls, Yosemite Valley, *Bol.;* Cascade Mts., *Lyall.*

101. **Z. Californicus,** Mull.
Hab. on shaded rocks, Marin Co.; Dardanelles Cañon, etc., *Bol.*

Z. cæspitosus, Mitt. A new species formed on sterile specimens collected on Vancouver Island by *Lyall*, appears, from the description, to belong to this species.

ULOTA, Mohr.

102. **U. phyllantha,** Brid.
Hab. Vancouver Island, *Wood.*

This division of the Orthotricheæ has not yet any representative from California.

ORTHOTRICHUM, Hedw.

103. **O. cupulatum,** Hoffm.
Hab. on metamorphic limestone rocks, near the Russian River, Ukiah, redwoods, deep gulches, *Bol.*

104. **O. Sturmii,** Hoppe & Hrnsch.
Hab. on shaded rocks, Yosemite Valley, *Bol.*

105. **O. Texanum,** Sulliv.
Hab. on rocks and trees, common in California, and extremely variable, *Bol.*

Var. *B. globosum*, Lesqx. Capsula breviori, subglobosa, pedicello longiori emersa, calyptra colore nitente brunnea, caule breviori, foliis humiditate erectis.

This form has a peculiar appearance, and seems, at first sight, a distinct species. But I do not find any good character to separate it. The peristome has either fugacious slender cilioli, or short incipient large ones, or none. A peculiar character of this species, and its varieties, which at once separates it from *O. anomalum*, is the black color of the spores.

106. **O. speciosum,** Nees.
Hab. on trees, *Bol.;* Fort Colville, *Lyall.*

Among the numerous varieties of this species, two forms, collected by Mr. Bolander, merit to be noted.

1st var. *polyanthum*, Lesqx. Læte viride ; foliis caulinis laxe imbricatis, humiditate appressis, comalibus longioribus, floribus masculis pernumerosis.

It has long slender branches, and a male bud in the axils of nearly each leaf.
Hab. on rocks, Big Trees.

2d var. *brevicaule*, Lesqx. Pallide vel luteo viride; cæspitibus compactis, sicut pulvinatis ; caule brevi, theca terminali, pedicello longiori exserta.
Hab. same as the former.

M. Mitten quotes still *O. elegans*, Schwægr., (from British Columbia, *Lyall*) a variety less distinct from the typical form than both the above described ones.

107. **O. rupestre,** Schl.
Hab. on rocks, Big Trees, *Bol.*

108. **O. rivulare,** Turn.
Hab. roots of elm trees and posts in water, Anderson Valley, etc., quite common, *Bol.*

109. **O. cylindrocarpum,** Lesqx. Pusillum, monoicum subpulvinatum. Caulis simplex vel parce ramosus, obscure viridis, inferne nigrescens. Folia in sicco appressa, madefacta erecto appressa, e basi latiori elongato-lanceolata acuta vel subobtusa nervo valido cum apice evanido carinata, margine e basi fere usque ad apicem revoluta, areolatione ovato-quadrata minuta papillosa versus basim polygono-elongata. Folia perichætialia vix longiora. Flos masculus in ramo proprio sub perichætio innovante, raro axillaris. Capsula in pedicello brevi, exserta, cylindrica, vel cylindrica-ovalis, pallide viridis vel luteola. Peristomii dentes 16 per paria approximati, albidi ciliis 8 robustis, basi dilatatis æquilongis, duplici serie cellularum formatis, separati. Operculum conicum, margine rubellum vaginula calyptraque anguste conica plicata, valde pilosæ.

Hab. on trees, Oakland, common, *Bol.*

This diagnosis completes the short comparative description given of this species in the Trans. Amer. Phil. Soc., vol. 13, p. 6. It is very small, not larger than the small forms of *O. strangulatum*, Beauv., with which it has some affinity by the peristome and form of the leaves.

110. **O. Kingianum,** Spec. nov. Monoicum, cæspitoso pulvinatum. Caulis erectus, pollicaris parce dichotome ramosus, inferne brunneus, superne obscure viridis. Folia humida erecto-patentia, breviora, ovato-lanceolata acutiuscula nervo carinata, e basi usque sub apice revoluta, reticulatione inferiori quadrato-elongata vel rectangulari, superiore quadrata, obscure granulosa et minute papillosa. Folia perichætialia conformia vix longiora. Capsula in pedicello 2–3 lineas longa, exserta, ovalis, brunnea lævis, collo brevi in pedicello attenuata, ore constricta, peristomii 16 dentes pallidi, breves, obtusi vel erosi germinati ciliis 8 interpositis e duplo serie cellularum compositis brevioribus. Calyptra elongata capsulam ad basim usque integens, sublævis.

Hab. rocks near the falls of the Yosemite Valley, *Bol.*

Distinguishable from *O. anomalum*, Hedw., which this species most resembles, by its peristome, and from *O. Hutchinsiæ*, Hook. and Tayl., by the areolation of its leaves and other indicated characters. Appears also nearly related to *O. consimile*, Mitt. But the author says of his species: *theca siccitate plicata, ciliis simplicibus æquilongis, calyptra ramentosa*, characters at variance with those of our species.

111. **O. consimile,** Mitt.

Hab. Vancouver Island, on trees, *Lyall.*

112. **O. Columbicum,** Mitt.

Hab. same as the former, *Lyall.*

113. **O. Coulteri,** Mitt.

Hab. California, *Coulter.*

114. **O. pulchellum,** Smith.

Hab. Clear Lake, *Bol.* Also communicated from Eureka and Vancouver Island by the same.

115. **O. Lyellii,** Hook.

Hab. on trees, very common in California, *Menzies, Bol., Big., Bauer, Lyall, Wilkes' U. S. Exp., etc.*

Var. foliis eorumque papillis longioribus, Sulliv. & Lesqx.

Musc. Exsicc. Amer., Ed. 2d, No. 185.

O. Menziesii, W. Hooker, Ms.

O. papillosum, Hampe.

Hab. same as the former.

All the authors who have examined this moss remark, that by its general appearance, it is indeed far different from the European species; but the analysis fails to

show a specific difference. Among the great number of specimens collected by Mr. Bolander, all the transitional varieties may be followed from the European type to the largest forms with very long stems, leaves, capsules and papilla. One of the most marked varieties has short stems, longer, nearly cylindrical exserted capsules borne on a longer pedicel, with the calyptra covering the whole capsule and part of the pedicel, and spiniform or branching papillæ of the leaves.

TETRAPHIS, Hedw.

116. **T. pellucida,** Hedw.
Hab. redwoods, on logs near Big River City, very rare, *Bol.;* Fort Colville, *Lyall.*

ENCALYPTA, Schreb.

117. **E. vulgaris,** Hedw.
Hab. Monte del Diablo ; Oakland hills, *Bol.;* Fort Colville, *Lyall.*

118. **E. rhabdocarpa,** Schw.
Hab. Cascade Mts., *Lyall.*

119. **E. ciliata,** Hedw.
Hab. spray of Nevada Falls, Yosemite Valley, in very large and fine specimens, *Bol.;* also banks of Russian River, near Ukiah.

SPLACHNACEÆ.

TAYLORIA, Hook.

120. **T. serrata,** Hedw.
Hab. Fort Colville, *Lyall.*

SPLACHNUM, Linn.

121. **S. melanocaulon,** Schw.
Hab. California, as indicated by Mitten.

FUNARIACEÆ.

PHYSCOMITRIUM, Brid.

122. **P. pyriforme,** Brid.
Hab. wet banks, Dardanelles, and swamps near San Rafael, *Bol.*

ENTHOSTODON, Schwægr.

123. **E. Bolanderi,** Lesqx.

Hab. on clayey ground, near San Francisco, *Bol.*

124. **E. Templetoni,** Schw.
Hab. swamp near Mendocino, Coast Range, very rare, *Bol.*

FUNARIA, Schreb.

125. **F. Californica,** Sulliv. & Lesqx., Musci Exsicc. Amer., Ed. 2d, No. 238. Pusilla; folia coronalia in gemmula congesta, vel erecta, oblonga, breviter acuta, integra, fere continuo-costata; capsula in pedicello brevi-recto, sicco sinistrorsum torto, sub pyriformi-oblonga, erecta, æqualis, vix asymetrica; operculum convexo-conicum, calyptra et peristomium generis, annulus nullus.
Hab. on clayey soil, Auburn, Ukiah, etc., *Bol.*

Is much like a small *Enthostodon*, the capsule being generally straight and symmetrical. The peristome is double, the internal being glued to the outer one to above the middle of the teeth. The reticulation of the leaves is remarkably close for a species of this genus.

126. **F. calcarea,** Wahl.
A var. *B. patula*, Schp.
Hab. on the ground, Mission Dolores; Mt. Diablo, *Bol.* *Funaria Muhlenbergii*, Schwægr, mentioned by Sullivant, as found by Dr. Bigelow near the crossing of the Colorado, is referable to this species.

127. **F. hibernica,** Hook.
Hab. Cajon Pass, Sierra Nevada, *Big.*

128. **F. hygrometrica,** Hedw.
Hab. California, *Bol.*, *Big.*, *Wilkes' U. S. Exp.*; Fort Colville and Vancouver, Island, *Lyall.*

Var. *C. calvescens*, Schp.
Hab. rocks in cañons of the American River, *Brew.*

129. **F. convoluta,** Hampe.
Hab. on the Sierra Nevada Mts., alt. 3,000 to 5,000 feet, *Bauer.*

130. **F. microstoma,** Brch. & Schp.
Hab. Soda Springs, Upper Tuolumne, 9,700 ft., *Bol.*

Appears to be abundant there; the specimens are very fine.

BRYACEÆ.

BRYUM, Dill.

§ 1. LEPTOBRYUM, Schp.

131. **B. pyriforme,** Hedw.

Hab. around Clear Lake and Mt. Dana, common from 8,000 to 11,000 ft., *Bol.;* moist banks of Sonora Pass, *Brew.;* banks of streams, Cajon Pass, *Big.;* Cascade Mts., *Lyall.*

§ 2. WEBERA, Hedw.

132. **B. polymorphum,** Hoppe & Hrnsch.
Hab. Mt. Dana, mixed with *B. nudicaule*, Lesqx., rare, *Bol.*

133. **B. longicollum,** Swartz.
Hab. Cascade Mts., *Lyall.*

134. **B. nutans,** Schreb.
Hab. foot of Mt. Dana, *Bol.;* Cascade and Galton Mts., *Lyall.*

Var. *C. bicolor*, Brch. & Schp.
Hab. Mt. Dana, *Bol.;* banks of King's River, 4,000 ft., *Brew.*

135. **B. nudicaule,** Spec. nov. Dioicum, cæspitosum; cæspites compacti, inferne brunnei, superne virentes. Caulis basi tantum radiculosus, subpollicaris, gracilis simplex vel raro ex apice innovans; plantæ antherigeræ graciliores fructiferæque e basi usque versus summitatem subnudæ, folia minima squamæformia, erecto-apressa, pellucida gerentes. Folia comantia dense conferta, erecta, ovato lanceolata brevia, nervo valido sub apice evanido carinato-concava, subintegra vel apice obsolete denticulata; floralia intima breviora denticulata; plantæ sterilis basi interrupte foliosæ folia breviora. Theca in pedicello vix semi-pollicari, valde flexuoso horizontalis vel pendula, ovata, subventricosa, ore haud vel vix constricta collo brevi fusca, pachydermis. Peristomii interni dentes liberi angusti, elongati, sæpius laciniis irregularibus summo conati, ciliis nullis interpositis; operculum conicum vel plano convexum annulatum; annulus pallidus compositus, revolubilis.

Hab. Mt. Dana, 11,000 ft., *Bol.*

The male plants of this species are mixed in an abundance in the cæspites, and their terminal buds are thick with numerous anthers without or with a few short paraphyses. The perigonial leaves are broad, oval, short-pointed or obtuse, brown colored, and obscurely nerved. Some free anthers are also found, though rarely, in the axils of the perichætial leaves. The capsule is rarely symmetrical, but generally more or less inflated on the lower side. This moss agrees so well with the excellent description given by Muller (Bot. Zeit., N. 40, p. 328) of his *B. Drummondi* from the Rocky Mts., that I should have considered it identical, if it was not that Muller's moss has *cilia Weberæ duplicia brevia*, while ours has no trace of cilioli, and that also the former is *exannulata*, while the California moss has a pretty large white revolving annulus. Muller also does not mention the peculiar stem leaves of the flowers bearing plants, and the presence of anthers in the axils of the perichætial leaves. The areolation of the leaves is of a *Webera*, but short and broad.

136. **Bryum Bolanderi,** Spec. nov. Dioicum, laxe cæspitosum, depressum, pallide viride niteus. Caulis simplex, foliosus. Folia inferiora laxe imbricata, erecta, lanceolata; superiora comantia conferta, longiora, anguste lanceolata, nervo sub apice denticulato evanido. Planta mascula vix gracilior; folia perigonalia e basi late ovata concava in acumen longum flexuosum angustatum producta subintegra. Folia perichætialia conformia, vix longiora. Capsula in pedicello longiori rubello inclinata vel horizontalis, breviovata, in collum sat longum attenuata; peristomii dentes externi late brevesque, interni longiores ciliis vel nullis vel binis rudimentariis interjectis. Operculum conicum apiculatum; annulus compositus.
Hab. foot of Mt. Dana, *Bol.*

Distinct from the former by its longer capsule of a thinner texture, narrowed at the mouth, and borne on a longer pedicel; by its shining color, its long, narrow, strongly denticulate leaves, the form also of the perigonial leaves, etc. The perichætial leaves do not have any anthers in their axils. A fine species, rather related to *B. crudum*, Schreb.

137. **B. cucullatum,** Schwægr.
Hab. Mt. Dana; rare, *Bol.*

138. **B. crudum,** Schreb.
Hab. around Clear Lake and near the Big Trees, on shady rocks, *Bol.;* Fort Colville, *Lyall.*

139. **B. Ludwigii,** Schwægr.
Hab. foot of Mt. Dana, 9,000 to 10,000 ft., *Bol.;* Cascade Mts., *Lyall.*

The form collected by Mr. Bolander is robust, has thick branches and open leaves.

140. **Bryum Tozeri,** Grev.
Hab. on the ground, borders of ditches and roads around San Francisco, Oakland, etc., *Bol., Big.*

141. **B. albicans,** Wahl.
Hab. wet banks, Dardanelles Cañon, *Bol.;* Galton Mts., *Lyall.*
Var. *gracilior*, capsulis brevioribus, etc.
Hab. on rocks watered by springs near San Francisco, *Bol.*

§ 3. BRYUM, Dill. emend

142. **B arcticum,** Brch. & Schp.
Hab. foot of Mt. Dana, *Bol.*
It slightly differs by the shorter capsule. Specimens few and deoperculate.

143. **B. cernuum,** Brch. & Schp.
Hab. foot of Mt. Dana, *Bol.*

144. **B. inclinatum,** Brch. & Schp.
Hab. on rocks at Clark's, Yosemite Valley, *Bol.*

145. **B. Warneum,** Brid.
Hab. foot of Mt. Dana, 9,000 to 10,000 ft., borders of ditches; abundant, *Bol.*

There is no difference whatever between this and the European moss. The flagelliform, twisted, nearly naked branches are extremely numerous.

146. **B. intermedium,** Brid.
Hab. on wet ground, Big Trees; on the ground near Crescent City; Mt. Dana, *Bol.;* Sonora Pass, mixed with *B. pyriforme, Brew.;* also found by Bigelow—no locality marked.

147. **B. cirrhatum,** Hoppe & Hrsch.
Hab. in a meadow near the Big Trees, 8,000 ft; Mono Pass, *Bol.*

148. **B. bimum,** Schreb.
Hab. Fort Colville and Galton Mountains, *Lyall.*

149. **B. torquescens,** Brch. & Schp.
Hab. Oakland, opposite San Francisco, *Big.*

150. **B. pallescens,** Schl.
Hab. Cascade Mountains, *Lyall.*

151. **B. subrotundum,** Brid.
Hab. on rocks, Yosemite Valley, *Bol.*

It differs from the European form only by the slightly longer capsule, rather horizontal than pendent.

152. **B. cæspiticium,** Linn.
Hab. on the ground, Yosemite Valley, *Bol.;* Silver Mts., and through the Sierra Nevada, from 7,000 to 8,000 ft.; *Brew.;* Cascade and Galton Mts., *Lyall.*

153. **B. argenteum,** Linn.
Hab. on the ground, San Francisco, *Bol.;* dry ravines, 50 miles west of the Colorado, *Big.;* rare.

154. **B. Californicum,** Sulliv.
Hab. near Benicia, *Big.;* common around San Francisco, on the ground, in grassy places, *Bol.*

155. **B. Bigelowii,** Sulliv.
Hab. trunks of trees above Sonora; base of the Sierra Nevada, *Big.*

156. **B. miniatum,** Spec. nov. Dioicum compacte cæspitosum. Caulis parce radiculosus simplex vel pluries sub capitulis inflatis innovante ramosus, gracilis, innovationibus quandoque gracillimis filiformibus. Folia sicca appressa, caulina laxe imbricata superiora in capitulum conferta concava, ovato-obtusa vel ovato-lanceolata obtusa, haud vel vix marginata, margine vix reflexa, nervo valido sub apice evanido instructa, e cellulis polygonis parietibus crassis reticulata. Folia perichætialia comalibus vix longiora, angustiora. Capsula

in pedicello longo rubello, inclinata, elongato-obconica, sub ore sub constricta, rufescens, operculo mamillari rubello, annulo latiori. Peristomii interni dentes angusti, ciliis crassis articulatis interpositis.
Hab. on moist rocks, Yosemite Valley.

This fine species is somewhat related to *B. pseudo-triquetrum*, with which it grows, but easily separated by the enumerated characters. The ramification is the same as in *B. Bigelowii*, Sulliv., from which it differs by the long capsule and the form of the leaves. The top of the branches is purplish, abruptly crimsoned, as if it had been plunged in carmine.

157. **B. occidentale,** Sulliv.
Hab. on ground, rocks, old logs, very common in California, *Bol.*, *Big.*, *Brew.*

This species is most intimately related to *B. capillare*, Linn., presenting most of the forms which are marked as varieties in the European species. I owe to the kindness of Prof. Hooker, specimens of a *Bryum* named *B. capillare*, by Mr. Mitten, collected in Vancouver Island, by *Lyall*, and which is evidently a large form of *B. occidentale*, and at the same time undistinguishable from *B. capillare*. It would be too long to enumerate here all the varieties of the California moss. The most marked one is a small form with slender innovations emerging from under more distinct and thicker capsules having with generally longer pointed leaves, narrow, cylindrical proportionally longer, broad red capsules and a proportionally broader annulus. But even the largest forms, whose capsules are generally pale brown and the leaves short, pointed, bear in the same tufts capsules of various color, from pale buff to dark red, with leaves also elongated or rather contracted into a piliform point. Though, from its larger annulus —especially its shorter pointed leaves and peculiar ramification—this species may be separated with some right from *B. capillare*, it does not appear possible to subdivide its varieties into species. One of these divisions is *B. Baueri*, Hampe, which, according to the author, differs from *B. capillare; statura minori, foliis brevioribus immarginatis, nervo excedente flexipili.*

158. **B. Oreganum,** Sulliv. Wilkes' U. S. Expedition, p 10, tab. vii.
Hab. Oregon, *Wilkes' U. S. Exp.*

159. **B. obconicum,** Hrnsch.
Hab. flanks of Santa Cruz Mts., 2,000 feet, *Brew.*

160. **B. Canariense,** Brid.
B. Billarderii, Schwægr.
Hab. cañons in Monte del Diablo, *Bol.*

161. **B. pseudotriquetrum,** Schwægr.
Cum var *B. gracilescens*, Schp.
Hab. wet rocks, Big Trees, *Bol.*; Fort Colville, *Lyall.*

162. **B. Duvallii,** Voit.
Hab. Eureka, *Bol.*, in good though sterile specimens; Fort Colville, *Lyall.*

163. **B. turbinatum,** Hedw.

Hab. Galton Mts., *Lyall.*

Var. *C. latifolium*, Schp.

B. Schleicheri, Schwægr.

Hab. wet meadows, Big Trees, *Bol.*

MNIUM, Linn. emend.

164. **M. affine,** Bland.
Hab. near Clear Lake, sterile, *Bol.*

165. **M. insigne,** Mitt.
Hab. borders of creeks, Devil's Cañon, *Bol.;* Vancouver Island, *Lyall, Wood.*

166. **M. venustum,** Mitt.
Hab. shaded rocks, Ukiah, etc., *Bol.;* Vancouver Island, *Lyall;* Oregon, *Wilkes' U. S. Exp.*

167. **M. medium,** Brch. & Schp.
Hab. Fort Colville and Cascade Mts., *Lyall.*

168. **M. spinulosum,** Brch. & Schp.
Hab. Fort Colville, *Lyall.*

169. **M. punctatum,** Linn.
Hab. Eureka. Sent by Mr. Bolander in good fruiting specimens.

170. **M. Menziesii,** Mull.
Hab. shaded rocks, banks of creeks, *Bol.*; Coast Range, *Big.;* Oregon, Port Discovery, *Wilkes' U. S. Exp.* First discovered in N. W. America by *Menzies*, and gathered also by *Scouler.*

MEESIA, Hedw.

171. **M. uliginosa,** Hedw.
Hab. found again in swamps, 9,000 ft., *Bol.;* swamp, 8,500 ft., *Brew.;* Mooyie River, *Lyall.*

172. **M. tristicha,** Brch. & Schp.
Hab. Tack River, *Lyall.*

173. **M. longiseta,** Hedw.
Hab. Oregon, *Wilkes' U. S. Exp.*

AULACOMNIUM, Schwægr.

174. **A. androgynum,** Schwægr.
Hab. especially on burnt stumps of *Sequoia sempervirens*, from the plains to the mountains, very common, *Bol., Brew., Big.;* Vancouver Island and Fort Colville, *Lyall.*

175. **A. palustre,** Schwægr.
Hab. swamps near Mendocino, *Bol.;* Cascade Mts., *Lyall.*

BARTRAMIA, Hedw.

176. **B. stricta,** Brid.
Hab. on rocks and ground near San Francisco, *Bol.*

It differs from the European form only by its pedicel, which is round and not square, obtuse under the capsule; agreeing, therefore, with Bridel's description, which does not mention this peculiarity.

177. **B. thyphylla,** Brid.
Hab. foot of Mt. Dana, ditches, abundant, *Bol.* It is the Alpine form, in compact tufts, with short stems and pedicels; also Cascade Mts., *Lyall.*

178. **B. fontana,** Brid.
Hab. Yosemite Valley, Big Trees; Clear Lake, on wet rocks, *Bol., Brew.* Appears common in the Sierra Nevada Mts.; Fort Colville, *Lyall.*

179. **B. Menziesii,** Turn.
Hab. on shaded rocks; very common in California, and gathered by all the botanists who have explored that country, *Menzies, Big., Brew., Bol., Bauer,* etc.

Var. foliis latioribus, brevius acuminatis, capsula longiore, ovato-elongata, ore la iori nudo, vel membrana integra circumdato.
Hab. on rocks, *Bol.*

With the normal form, whose capsule is oval, sometimes nearly round, Dr. Hampe has made a new species, under the name of *Glyphocarpa Baueri.* But the capsules of this normal form have generally a well developed peristome, though, indeed, this peristome is sometimes replaced by a pellucid membrane, lacerated in the form of irregular teeth, or even is totally wanting. The moss, which I consider as a variety as described above, has generally a naked mouth, though sometimes it shows traces of even a well formed peristome.

TIMMIA, Hedw.

180. **T. megapolitana,** Hedw.
Hab. Vancouver Island, *Lyall.*

POLYTRICHACEÆ.

ATRICHUM, Tal. Beauv.

181. **A. undulatum,** Tal. Beauv.
Hab. on rocks, Mission Dolores, *Bol.;* Oregon, *Wilkes' U. S. Exp.;* Fort Colville, *Lyall.*

182. **A. angustatum,** Bryol. Eur.
Hab. banks, Santa Cruz Mts., alt. 2,200 ft., *Brew.*

POGONATUM, Tal. Beauv.

183. **P. dentatum,** Menz.
Hab. pine woods of N. W. America, *Menzies;* clay banks in dense shade of the redwoods near Crescent City, *Brew.*

Prof. C. Muller says of this species: calyptra lævis; in my specimens it is rugose, like that of *P. urnigerum,* Brid., and, accordingly, the only difference which separates the Californian from the European species is the glaucous color of the more stronly dentate leaves.

184. **P. alpinum,** Roehl.
Var. *D. brevifolium,* Schp.
Hab. foot of Mt. Dana, borders of ditches, *Bol.*

185. **P. contortum,** Menz.
Hab. on shores of N. W. America, *Menzies.*

POLYTRICHADELPHUS, C. Mull.

186. **P. Lyallii,** Mitt.
Hab. foot of Mt. Dana, and around Clear Lake, *Bol.;* swamp, east side of the Cascade Mts., *Lyall.*

POLYTRICHUM, Dill.

187. **P. piliferum,** Schreb.
Hab. rocky places above Sonora, *Big.;* Vancouver Island, *Big., Lyall.*
Var. pilo brevi, serrato, foliis quandoque epiliferis.
Hab. Lassen's Peak, alt. 8,000 ft., *Brew.*
Var. *lævipilum, P. lævipilum,* Hampe.
Hab. Mt. Diablo and Coast range, *Bol., Bauer.*

188. **P. juniperinum,** Hedw.
Hab. California, from the plains around Mendocino, to the Yosemite Valley, common, *Bol.;* near Cajon Pass, *Big.;* abundant in woods, from 7,000 to 9,000 ft., Mt. Brewer, *Brew.;* Vancouver Island, *Lyall,;* Oregon, *U. S. Wilkes' Exped.*

BUXBAUMIA, Haller.

189. **B. aphylla,** Haller.
Hab. Cascade Mts., *Lyall.*

FONTINALACEÆ.

FONTINALIS, Dill.

190. **F. antipyretica,** Linn.

Hab. Swamps, in stagnant water and Coast Ranges in rivulets, *Bol. Big.*, Alpine Lake, near Silver Mts., *Brew.*

191. **F. Mercediana,** spec. nov. F. antipyretica habitu similis, differt: caule graciliori, distycho, raro trigono folioso; foliis acutius carinatis, plicatis, haud vel vix decurrentibus; areolis foliorum superne angustioribus, vacuis; alaribus brevioribus inflatis, paucis; peristomii interni, reti clathrato imperfecto; externi dentibus brevioribus, articulis distantibus, 18 to 20; operculo duplo breviori, capsulæ colore pallida.

Hab. on rocks, Merced river, *Bol.*

This species has the facies, color and peristome of *F. dalecarlica*, Brch. and Schp., differing essentially from it by the entire (not lacunose) teeth, the longer capsules, the flattened branches, etc.

DICHELYMA, Myr.

192. **D. uncinatum,** Mitt.

Hab. Fort Colville, *Lyall.*

193. **D. Swarzii,** Lndb.

Hab. upland swamps between King's and Kaweah rivers, *Brew.;* swamps near Mendocino city, and pools at the foot of Mt. Dana, *Bol.*; no fruit found.

This moss agrees in every point with Schimper's description of the species, and presents two forms far different in appearance. One, pale green colored, shining, with long, scarcely branching stems, and appressed, nearly straight leaves. It grows in prairie swamps, which are dry in summer. The other, black or brown colored, with stems much divided in horizontal short branches and falcate-uncinate leaves.

NECKERACEÆ.

NECKERA, Hedw.

194. **N. Menziesii,** Hook.

Hab. on rocks, in deep shaded gulches, *Bol.;* base of trees, near Crescent City, *Brew;* Fort Colville, *Lyall.*

From the Russian valley, Mr. Bolander has sent remarkable specimens, with leaves and branches covered with capillary filaments resembling tufts of confervæ, or of *Hypnum confervoides.* These filaments are generally simple, emerging from the

axils of the branch leaves, and bear very small oval-pointed, entire or slightly denticulate leaves, without costa and with a loose reticulation. Other specimens also gathered by Mr. Bolander, and marked "shaded rocks, Yosemite Valley," are of a pale green color, with short stems, and without any trace of stolons.

195. **Neckera Douglasii,** Hook.

Hab. on trees, Marin Co., Mendocino City, etc., *Bol.;* Oregon, *Wilkes' U. S. Exp.;* Vancouver Island, *Wood.*

ALSIA, Sulliv.

196. **A. Californica,** Sulliv.

Neckera Californica, Hook. and Arn.

Hab. on trees and rocks; very common along the coast, *Bol., Big.;* Oregon, *Wilkes' U. S. Exp.*

197. **A. longipes,** Sulliv. and Lesqx., Musci Exsicc. Amer., Ed. 2d, No. 399; Dioica, pinnato ramulosa, subfrondiformis, compressiuscula foliosa. Folia oblongo-lanceolata, breviter acuta, superne grosse serrata, minute ovali-areolata, costa ultramedia apice dorsali denticulato; perichætialia abrupte filiformi attenuata; capsula cylindracea, in pedicellum subuncialem perichætio quadruplo longiorem defluente; peristomio 1–2 ciliolato, operculo calyptraque *A. abietinæ.*

Hab. on rocks in deep cañons, Oakland, *Bol.*

198. **A. abietina,** Sulliv.

Neckera abietina, Hook.

Hab. on trees, common in California, and gathered by all the botanists who have explored the country.

ANTITRICHIA, Brid.

199. **A. curtipendula,** Brid.

Hab. Mt. Diablo, sterile, *Bol.* It is a peculiar form, with closely appressed leaves and julaceous branches. Oregon, *Wilkes' U. S. Exp.;* Vancouver Island, *Wood.*

Var. *C. gigantea,* Sulliv. & Lesqx., Musci Exsicc. Amer., Ed. 2d, No. 356. Valde robusta, atro-viridis, foliis latioribus, homomallofalcatis, capsula cylindrica longiori.

Hab. on rocks and trunks of living trees, Redwoods, *Bol.*

200. **A. Californica,** Sulliv.

Hab. on shaded rocks, and sandstone boulders, Oakland, *Bol.*

HOOKERIACEÆ.

HOOKERIA, Tayl.

201. **H. acutifolia,** Hook.

Hab. in a deep cañon, *Bol.*

This moss is the same in every point as that described under that name from the Atlantic States. No fruit has been found as yet.

202. **H. anomala,** Mull.
Hab. N. W. America, *Menzies.*

LESKEACEÆ.

ANOMODON, Hook & Tayl.

203. **A. Californicum,** spec. nov. Cæspites laxi prostrati vel dependentes, fusco-lutei, inferne brunnei. Caulis parce ramosus, gracilis, sicco foliis appressis angulatus. Folia quadrifariam imbricata, humida aperta, basi semi amplectente auriculato-decurrentia, late ovata, acuta, margine replicata, nervo valido sub pallido cum apice evanido carinata, cellulis alaribus oblongis elongatis, inde superne ovato-quadratis utraque pagina papillosis, papillis ad auriculas longioribus, spinosis.
Hab. on rocks, Mt. Diablo, sterile, *Bol.*

A fine species, without near relation to any other described. The borders of the leaves are abruptly plicate backward to above the middle of the leaves, and only reflexed near the point.

FABRONIACEÆ.

FABRONIA, Raddi.

204. **F. pusilla,** Raddi.
Hab. bark of trees, Oakland, *Bol.*

HYPNACEÆ.

PTERIGYNANDRUM, Hedw. emend.

205. **P. filiforme,** Hedw.
Hab. on shaded boulders and trees, *Bol.*, *Big.*

Var. nervo validiore elongato, foliis apice cristato-serratis. *Leptohymenium cristatum,* Hampe.
Hab. on rocks, Sierra Nevada, *Bauer.*

PTEROGONIUM, Swartz.

206. **P. gracile,** Swartz.
Hab. on rocks near the bay of San Francisco, common, *Bol.*, *Big.* California, *Wilkes' U. S. Exp.*

Var. statura graciliori, ramis magis filiformibus, foliis duplicato-serratis.

Leptohymenium duplicato-serratum, Hampe.

Hab. on trees in California, *Bauer*.

This species is still more variable than the former.

HYPNUM, Dill.

§ 1. THUIDIUM, Schp. Bryol. Eur.

207. **H. Blandowii,** Web. & Mohr.

Hab. Fort Colville, *Lyall*.

208. **H. crispifolium,** Hook.

Hab. N. W. America, *Menz.;* on shaded ground and rocks, Oakland, etc., *Bol.;* Vancouver Island, *Wood*.

209. **H. (Leskea) laxifolium,** Hook.

Hab. coast of N. W. America, *Menz*.

Nothing like this species of Hooker has been found in California by recent collectors. It may be a variety of the former species, or appears, at least, to belong to this section.

210. **H. remotifolium,** Grev.

Hab. N. W. America.

An obscure species.

211. **H. Whippleanum,** Sulliv.

Hab. California, *Big*.

212. **H. leuconeurum,** Sulliv. et Lesqx., Musci Exsicc. Amer., Ed. 2d. Hypno Whippleano peraffine, cæspite densiore, operculo breviore, pedicello lævi etc, distinguendum.

Hab. on the trunks of *Quercus agrifolia*, Oakland; in woods, but more common on moist soil of shaded hillsides, Oakland.

213. **H. calyptratum,** Sulliv.

Hab. near Los Angeles, on the ground, *Big*.

§ 2. ISOTHECIUM, Brid.

214. **H. myosuroides,** Linn.

Hab. near San Francisco, dry woods, *Big*.

Perhaps a variety of the next.

215. **H. stoloniferum,** Hook.

Hab. on trees, in the Redwoods; very common in California, *Menzies, Bol., Big*. Oregon, as var. *B.* of *H. myosuroides*, in Sulliv., *Wilkes' U. S. Exp.;* Vancouver Island, *Wood*.

This species is particularly polymorphous. In order to elucidate the remarkable disposition of this moss to modify its form under peculiar circumstances, especially

under the influence of wind and fog, Mr. Bolander sent me a large specimen, whose branches on one side are elongated in slender filiform stolons, from six inches to one foot long, while on the other side the stem and branches are thick, short, with large leaves. The filamentous part, according to Mr. Bolander's remarks, was hanging from a branch exposed to wind and fog, while the other part, presenting a normal development, was, by its extension to the other side of the trunk, preserved against this action. Specimens of *H. circinale* and *H. Nuttallii* are subjected to the same peculiar development. I can but therefore consider the multiplication of species from such polymorphous mosses as a hazardous task. I have admitted as a species the more distantly related form of *H. Breverianum*, which, growing in dense tufts on dry rocks, has a black color, short stems, short obtuse leaves, and in appearance is totally different from *H. stoloniferum*. But even on dry rocks, the part of the cæspites which is not directly exposed to the sun's influence passes to a yellowish green color, and bears some more elongated attenuate branches, even stolons, showing more and more an approach to *H. stoloniferum* or *H. myosuroides*, for Professor Muller does not separate these species. Mr. Mitten has described a number of forms which are more or less intimately related to *H. stoloniferum*, and which, if the opinion of Muller is right, should be reunited as well as *H. Breverianum* as varieties of *H. myosuroides*.

216. **H. Breverianum,** Lesqx.
Hab. on metamorphic sandstone around San Francisco, *Bol.*

217. **H. aggregatum,** Mitt.
H. Breverianum var., Sulliv. and Lesqx. Musci Exsicc. Amer., Ed. 2d, No. 427,
Hab. in deep cañons; Oakland, on trunks, *Bol.*

218. **H. aplocladon,** Mitt.
Hab. N. W. coast of America, *Douglas.*

219. **H. lentum,** Mitt.
Hab. same as the former, *Douglas.*

§ 3. CAMPTOTHECIUM, Bryol. Eur.

220. **H. lutescens,** Hnds.
Hab. Vancouver Island, *Lyall;* California, *Coulter;* N. W. Coast, *Douglas.*
Received from Victoria, Oregon, through Mr. Bolander.

221. **H. Nuttallii,** Wills.
Hab. on trees, California, common, *Bol., Big.;* Vancouver Island, *Lyall, Douglas.*

Var. stoloniferum, ramis elongatis, aggregatis filiformibus lutescentibus.

Hab. on trees. Sent by Mr. Bolander. A very remarkable variety. The stems are creeping, as in the normal form, and bear shorter and more slender capsules, and the crowded branches are elongated filiform, depending from the branches of trees.

222. **H. arenarium,** Lesqx.
Hab. on sand, around bushes near the shores, San Francisco, *Bol.*

223. **H. pinnatifidum,** Sulliv. and Lesqx., Musci Exsicc. Amer., Ed. 2d, No. 513. Ab Hypno aureo affinissimo distinguitur: capsula cernua annulo majori, foliis brevius filiformi acuminatis, reti multo laxiore denique inflorescentia revera dioica.

224. **H. Nevadense,** Spec. nov. Dioicum, laxe cæspitosum, robustum, lutescente viride. Caulis primarius repens pinnatim ramosus, ramis brevibus, horizontalibus vel longioribus, irregulariter divisis, arcuato curvatis. Folia lanceolata, sensim brevi-acuminata, homomallo-curvata, apice minute serrata, costa carinata, profunde biplicata, margine revoluta vel reflexa, cellulis alaribus perpaucis, irregulariter ovalibus. Capsula in pedicello rubello erecta vel sub cernua, ovato-cylindrica, longe rostrata, peristomii interni cilia vel rudimentaria, vel nulla; annulus compositus.
Hab. on rocks in the spray of Nevada and Bridal Veil Falls, *Bol.*

Is distinguished from *H. lutescens*, Huds., by its green color, larger thick stems and branches; the evidently pennate ramification, less marked, however, than in *H. aureum;* the alar reticulation scarcely marked by a few oval cells; by the large capsule, the peristome without cilia, etc. The leaves are more regularly and deeply plicate than in any other *Camplothecium.*

§ 4. BRACHYTHECIUM, Bryol. Eur.

225. **H. lætum,** Brid.
Hab. the Yosemite Valley. The plants are sterile, and the species not undoubtedly ascertained.

226. **H. salebrosum,** Hoffm.
Hab. Fort Colville and Pend' Oreille, *Lyall.*

227. **H. collinum,** Schl.
Hab. Cascade Mts., *Lyall;* Mr. Bolander sent it sterile from the Yosemite Valley.

228. **H. Hillebrandi,** Spec. nov. Monoicum, tenellum, cæspitibus intricatis condensatis sericeo-lutescentibus. Caulis erectus, plicatus, irregulariter subfasciculatim ramosus cum ramis undique divergentibus radiculosis. Folia laxe imbricata subsecunda, e basi ovata, sensim lanceolato-acuminata, concava, basim tantum plano reflexa, toto margine serrulata, costa medio vel paulo ultra evanida, areolatione angusta elongato-polygona, angulis dilatata, quadrato chlorophyllosa. Perichætialia pellucida, laxe areolata, plerumque enervia, e basi ovata, sensim in acumine longo, gracili erecto vel flexuoso subintegro attenuata. Capsula in pedicello breviusculo inferne rubello subrugoso, superne pallido lævi, brevis, turgide ovata, æqualis, erecto raro inclinata, sicca ore dilitata, operculo conico brevi obtuso truncato. Peristomii externi dentes longiores inferne pallide lutei, superne albidi, processus tenerrimi pellucidi dentibus perforatis ciliis duobus articulatis interpositis; annulus?

Hab. on rocks, Merced River, *Bol.*

A fine species related to *H. collinum* and *H. salicinum*. The leaves have about the same form as in this last, but are broader, though not as broad as in *H. collinum*, with a shorter costa. The essential difference is in the small, generally erect capsule, with a pedicel rough from the middle downward. The operculum, though found in plenty among the tufts, is detached from all the capsules. No trace of an annulus is left.

229. **H. declivum,** Mitten.

Hab. Pend' Oreille River, *Lyall.*

230. **H. vallium,** Sulliv. and Lesqx., Musci Exsicc. Amer., Ed. 2d, No. 506. Hypno læto inflorescentia, statura, foliatione et habitu accedens; distinctissimum autem caule rigidiore, pedicello scabro, foliorum cellulis quadratis ad basis angulos late decurrentes paucioribus, haud granulosis, etc.

Hab. on shaded metamorphic rocks, in deep cañons, *Bol.*

This species is apparently nearly related to the former, but the leaves are not denticulate from the base, and the costa is also not denticulate on the back.

231. **H. populeum,** Hedw.

Hab. Sierra Nevada, *Dr. Hillebrand.*

The specimens were communicated by Mr. Bolander; all the capsules are deoperculate.

232. **H. Bolanderi,** Lesqx.

Hab. on the ground, shaded by *Oreodaphne Californica*, rare, Oakland, *Bol.*

§ 5. SCLEROPODIUM, Bryol. Eur.

233. **H. illecebrum,** Schwægr.

Hab. rocks and ground, from the plain to the mountains, *Bol.* Extremely variable. In compact dark brown tufts, with densely imbricated, ovate-obtuse, nearly entire leaves and julaceous branches. Hab. in the water of the Yosemite Valley. In subdendroidal divisions, with acute and nearly entire leaves. Hab. deep cañons, etc. It is remarkable that no species of the genus *Scleropodium*, so widely distributed in California, has been found, except by Mr. Bolander.

234. **H. cæspitosum,** Wills.

Hab. on shaded rocks, and on the ground in the redwoods, Oakland, etc., *Bol.*

235. **H. Californicum,** Lesqx.

Hab. on shady, sandy ground, and sand around San Francisco, *Bol.*

§ 6. EURYNCHIUM, Bryol. Eur.

236. **H. strigosum,** Hoffm.

Hab. wet ground, Big Trees, *Bol.*; Fort Colville and Galton Mts., *Lyall.*

237. **H. Stokesii,** Turn.
Hab. on shaded ground and rocks, very common, *Bol., Big.;* Vancouver Island, *Lyall, Wood.*

238. **H. Oreganum,** Sulliv.
Hab. in woods, on decaying logs or on the ground, *Bol., Brew., Big.;* Puget Sound, Oregon, *U. S. Wikes' Exp.;* Vancouver Island, *Wood.*

§ 7. RYNCHOSTEGIUM, Bryol. Eur.

239. **H. rusciforme,** Weis.
Hab. in a rivulet near Mt. Diablo, sterile, *Dr. Hillebrand, Bol.*

§ 8. THAMNIUM, Bryol. Eur.

240. **H. Bigelowii,** Sulliv.
Hab. on shaded rocks, in cañons, *Big., Bol., Brew.*

241. **H. Neckeroides,** Hook.
Hab. Vancouver Island, *Wood.*

According to Mitten, we have, in the United States, in this division of the Hypnaceæ, *H. Neckeroides,* Hook., found by Drummond in St. Louis; *H. alopecurum,* sent from Boston, and *H. Alleghaniense,* Mull. Though we have examined, with Mr. Sullivant, a great number of specimens, either collected by ourselves or sent from various points of the United States, we have never been able to find any species different from that of *H. Alleghaniense,* Mull., which differs from *H. alopecurum* by the inflorescence only. This *H. Alleghaniense* is the same moss as No. 119 of Drummond, *H. Neckeroides,* quoted by Mitten. And as the male flowers are rarely found on fruiting plants, incomplete specimens are often taken for *H. alopecurum.* I believe, therefore, that these three species, quoted by Mitten, are, for American specimens, referable to the same *H. Alleghaniense,* Mull. *H. alopecurum* from Europe, and *H. Neckeroides,* Hook., from New Zealand, are indeed different, but not yet found in our country.

§ 9. PLAGIOTHECIUM, Bryol. Eur.

242. **H. pulchellum,** Dicks.
Hab. Fort Colville, *Lyall.*

243. **H. turfaceum,** Lndb.
Hab. same as the former, *Lyall.*

244. **H. elegans,** Hook.
Hab. near Nootka, Vancouver Island, *Menzies.*

245. **H. denticulatum,** Lin.
Hab. Coast Range, Mendocino City; on a fork of redwood tree, Jackson Valley, *Bol.;* rare, Fort Colville, *Lyall.*

246. **H. undulatum,** Lin.

Hab. swamps near the coast, Mendocino, *Bol.;* Oregon, *U. S. Wilkes' Exp.;* Fort Colville, *Lyall;* indicated by Muller, as found at Cape Disappointment.

§ 10. AMBLYSTEGIUM, Bryol. Eur.

247. **H. compactum,** Mull.

H. serpens var. compactum, Hook.

Hab. on the ground around springs, Big Tree grove, *Bol.;* near Fort Colville, *Lyall.*

248. **H. serpens,** Lin.

Hab. on the roots of bushes, in swamps, *Bol.;* on the ground, near Crescent City, *Brew.;* common in California, *Big.*

249. **H. radicale,** Beauv.

Hab. Galton and Cascade Mts., *Lyall.*

According to Mr. Mitten, who mentions this species, which he calls a much misunderstood species, it differs from *H. serpens* in its narrower and longer leaf cells. If we admit the descriptions of Schimper and other authors, and rely for the nomenclature on our American specimens as types, the contrary should have been asserted. For, indeed, *H. radicale,* as it is generally understood, has the leaf cells shorter and proportionally broader, and a longer and stronger costa than *H. serpens,* Lin. About the understanding of this troublesome species, I readily admit what Mr. Sullivant says in his Icones, p. 200: "*H. orthocladon, H. contextum, H. tenax, H. inordinatum, H. varium,* attributed to this country only, are (together with a few other supposed species, included *H. radicale,* found both here and in Europe) so variable in their characters, and pass so gradually into each other, that it appears quite impracticable to define their specific limits, or to separate them from large forms of *H. serpens,* to which they have been referred by Muller and others."

250. **H. orthocladum,** Beauv.

H. varium, Hook. and Wills., in Drummond.

Hab. borders of springs, and among willows, Little Lake Valley, *Bol.;* Pend' Oreille River, *Lyall.*

251. **H. riparium,** Lin.

Hab. Mill Falls, Oakland, and Big Tree grove; around springs, *Bol.;* near Crescent City, *Brew.;* wet places, *Big.*

§ 11. CAMPYLIUM, Sulliv.

252. **H. hispidulum,** Brid.

Hab. Mooyie River, *Lyall.*

§ 12. HARPIDIUM, Sulliv.

253. **H. aduncum,** Hedw.

Hab. a swamp in San Francisco, *Bol.*

254. **H. uncinatum,** Hedw.
Hab. Bridal Veil Falls, Mono Pass, near Merced River, Big Tree grove, and foot of Mt. Dana, *Bol.;* wet banks near King's River, *Brew.;* Cascade Mts., *Lyall.*

255. **H. commulatum,** Hedw.
Hab. east side of Mono Pass, sterile, *Bol.*

256. **H. filicinum,** Linn.
Var. Vallis-clusæ.
Hab. Fort Colville, *Lyall.*

§ 13. RHITIDIUM, Sulliv.

257. **H. robustum,** Hook.
Hab. Western Coast of North America, *Menzies;* Fort Colville, *Lyall.*

§ 14. DREPANIUM, Schp.

258. **H. fertile,** Sendt.
Hab. Big Trees, on humected rocks, *Bol.*

A small specimen only was received. It has the essential characters, the form of the leaves, the areolation, capsule, etc. But no male flower could be found on the plants. The species is therefore somewhat uncertain.

259. **H. subimponens,** Lesqx.
H. plumifer, (?) Mitten.
Hab. on shaded rocks in woods, from the plain, Oakland, to the mountains, Big Trees, Long Valley, *Bol.;* Vancouver Island, *Lyall.*

It is still doubtful if this species is the same as that described by Mr. Mitten as *H. plumifer* (among other characters) with *operculo brevi subulato rostrato,* and the general appearance of *H. Crista-Castrensis,* Linn. In our moss the lid is conical, sometimes obtuse, sometimes more elongated, pointed, but never rostrate; and its likeness to *H. imponens* is so remarkable that it is difficult to separate both species.

260. **H. circinale,** Hook.
Hab. base of trees, Siskiyou Mts., 4,000 to 5,000 ft., *Brew.;* on living redwoods exposed to winds and fogs, 2,000 to 2,500 ft., *Bol.;* Oregon, *Wilkes' U. S. Exp.;* Vancouver Island, *Lyall.*

§ 15. LIMNOBIUM, Bryol. Eur.

261. **H. arcticum,** Sommerf.
Hab. foot of Mt. Dana, entirely submerged, in streamlets, apparently very rare, and seen but once, *Bol.*

§ 16. HYPNUM, Schp. Synop.

262. **H. giganteum,** Schp.
Hab. Fort Colville, *Lyall.*

263. **H. cuspidatum,** Linn.
Hab. Pack River, *Lyall.*

§ 17. HYLOCOMIUM, Bryol. Eur.

264. **H. loreum,** Dill.
Hab. Oregon, *Wilkes' U. S. Exp.;* Vancouver Island, *Lyall, Wood.*

265. **H. splendens,** Dill.
Hab. Oregon, *Wilkes' U. S. Exp.;* Vancouver Island, *Lyall, Wood.*

MEMOIRS

PRESENTED TO THE CALIFORNIA ACADEMY OF SCIENCES.

VOLUME I.

II. *Principles of the Natural System of Volcanic Rocks.*

By F. Baron Richthofen, Dr. Phil.

[Presented, May 6th, 1867.]

Introductory. Among the features peculiar to modern Geology may be noticed a revival of that speculative tendency which prevailed among the cultivators of this science at the close of the last century. But while in those early times imagination exerted a dominant influence in the framing of hypotheses, and discussions between the adherents of different doctrines were conducted with all the bitterness peculiar to such struggles, when neither party has a firm basis upon which to found its arguments, the constant ascendency of the spirit of the inductive method has imparted to those theories more recently propounded a more logical and scientific form, while, at the same time, the increasing amount of positive knowledge has given to the different doctrines a more varied and more definite character, and enlarged the scope of dissenting views.

This renewed tendency to systematize and theorize, which is especially conspicuous in the records of the last twenty years, must be ascribed, partly, to the vast amount of well-established facts gathered during the previous decades, and which have since been multiplied and intensified in a constantly increasing ratio, as regards depth and distinctness of observation as well as the geographical area over which they extend; partly, and in no less degree, to the rapid progress made by those sciences on which geology has to draw for the general laws which are alone capable of affording a philosophical guide to speculation on the basis of facts gained by observing and comparing. The advance of the chemical and physical sciences, especially, has had a

powerful influence, by allowing an immediate application to geological problems of such general laws as are established beyond any doubt. Besides, the improvement of the practical methods applied in chemical and physical laboratories has given rise to the execution of numerous experiments, which were made with a view of imitating the processes applied in the great natural laboratories. They suggested frequently the causes of facts disclosed by the examination of a certain region, or obtained by comparing the observations made in different countries on one certain subject.

It appears to be mainly due to these causes that a number of theories have been proposed, in rapid succession, relating to the origin of rocks, to the mode and causes of metamorphism, to the agencies of vulcanism, to the structure and mode of formation of mountain ranges, to the structure of the entire globe, and other cognate subjects. It will be admitted, even by those who are most strongly opposed to theorizing, that geological science has in this way been promoted and enriched in various respects; since there is scarcely a theory which, even if insufficient to explain what it undertakes, has not some truth in it, or is applicable to some extent in certain cases, or has at least, even when proving to be erroneous itself, led to discussions on subjects of high interest, which is indeed a result of no little value. In reviewing the theories proposed on any particular subject, we find them, it is true, often in apparent contradiction with each other; yet almost every one is based upon arguments drawn from observed facts, and there are probably very few which will ultimately be entirely abandoned. The immense range of varied processes as applied by nature allows the applicability, in a limited way, of many a theory in certain instances, while in others it may be refuted on no less valid grounds; and the struggle between the defenders of different doctrines is often founded only in the difference of their standing-points. What appears to be true in one instance is frequently not applicable in others; it is the bold generalizations which render theories so often untenable in that form in which they are usually first expressed. An instructive example is presented by the different theories which have been proposed for explaining the mode of formation of mineral veins. Almost every one of them was based upon a limited range of observations, and was, from its first application to a few instances, extended to the generality of veins. Numerous exceptions to it were then found, leading to the rejection of the first, and the establishment of a different, theory, which, in its turn, shared a similar fate. Obscure as this subject still is, we are able to state this as certain, with our present state of knowledge, that every mineral vein is the product, not of one simple but of complex processes. Nearly every one of the theories proposed will, therefore, have its limited range of applicability, inasmuch as the agent it suggests may have been especially active in the formation of the veins of a certain order, while the same agent may have played a subordinate part in regard to the origin of other veins which were chiefly due to processes of another kind.

This instance points clearly towards the one principal cause of the divergence of opinions in regard to some of the most important geological questions. This cause is the want of latitude of the basis upon which arguments are founded. Conclusions which are obtained by reasoning on geological subjects solely on the strength of chemical analysis, are, when generalized, often found to be utterly in discordance with the

facts revealed by geological observation; and how unsatisfactory general theories may be when based upon the latter alone, is sufficiently exemplified by the fantastical attempts made in all ages of geological science to interpret the geological structure of the world from that of a limited region. The basis for argumentation can therefore never be broad enough, and its enlargement should be, as it indeed is, one of the chief objects of geological science. But it is not sufficient to content ourselves with an accumulation of primary observations, which are in fact being infinitely increased by the conjoint labors of geologists in all countries: it should be a higher object of the student of geology, to compare the established results of observation, and to investigate their mutual relations. The study of the structure of one mountain range, or of several ranges comprised within a limited district, may lead to the establishment of an elaborate theory of the mode of their formation, which may apparently answer perfectly well in that one case, but may be found inadmissible when generalized, even in those cases where, by imperfect observation, one would expect to detect a great similarity to the structure first observed. But in determining those features which are common to a number of mountain ranges, or to certain orders of them which we may discern among their generality, we may aspire to form conclusions which are more generally applicable. It is particularly the auxiliary branches of geology to which these remarks apply. The value of observations made in limited regions, or from a limited point of view, on subjects such as the outlines of the morphological features of the continents, the occurrence of mineral springs, the structure of mineral veins, the age of those among them which carry a certain metal, the generality of volcanic phenomena, the mode of action of earthquakes, the nature of certain kinds of rocks, and their part in the structure of the surface of the globe—cannot be fully realized unless the comparative method is applied in as wide a scope as we may be able to do, and the mutual relations among the different modes of manifestation of force, or among the properties of the kinds of matter upon which it acts, or the bearing of all these relations to each other and to the evolution of the globe, are investigated from as many points of view as we may detect, and in as many combinations as possible. We may then be able to gain a foundation for argumentation on more involved problems, consisting not of imperfect premises, nor of a confused accumulation of facts, but of established truths of a higher order.

The mode of origin of the non-foliated crystalline rocks, made up of silicates,* is among those subjects which have at all times, but at no time more than of late, commanded a great deal of attention, and given rise to the establishment of numerous theories, each of which was applied in a general way, if not by its author, then by his followers. It is well known how conflicting they apparently are, and what weighty arguments have been brought in favor of as well as against each of them. The only method, promising success, of weighing the merits of these different theories, or of modifying them in accordance with the general advance of science, appears to be, to

* I have for these applied the name "eruptive rocks" in the following pages, considering that, wherever we have occasion to observe them, they are not at their original seat, but ejected from it towards the surface. The reasons supporting this position will be more fully mentioned in the chapter on the origin of volcanic rocks.

ascend from the examination of the nature of these rocks to that of their mutual relations, to investigate these from as many points of view as we can discover, in regard to physical and chemical properties, mode of occurrence and age, as well as in regard to geographical distribution: that is, to try to establish the natural system of eruptive rocks. The results so obtained may then, in accordance with what we just remarked in a general way, be applicable to reasoning on remoter questions, of which we can only attempt to find the most probable solution. They regard chiefly the causes of those relations, the mode of origin of the eruptive rocks, and the processes connected with their ejection. The intricate nature of the subject, and the fact that the present changes on and below the face of the globe, as well as the events of the past, are often but dimly and imperfectly perceptible to our observation, demand that we should concentrate our endeavors in exploring first the laws of that which is definite and constant within the infinite range of phenomena, and await further experience to arrive at an explanation of those isolated facts which form apparent exceptions to the order of things.

It is with these views that the following pages were written. They extend chiefly over the comparatively limited, and yet very extensive class of "volcanic rocks," and are offered as a mere elementary attempt, which is necessarily very imperfect. The application to exact reasoning of the numerous observations which have been made on the subject of volcanic rocks in different countries, is nearly prevented by the extraordinary discrepancy existing in regard to the mode in which the names of rocks are used by different authors. The first condition of a uniform and harmonious mode of observation on volcanic rocks, and the phenomena connected with them, is the application of a uniform system of nomenclature.

In concluding these preliminary remarks, I dare express the hope that some indulgence may be had with the imperfections of this essay, if it is taken into consideration that it was written on the Pacific coast, where chemical laboratories are unknown, libraries scarce, and little opportunity is afforded of becoming acquainted with the current geological literature. I fulfill a deep-felt duty if I tender at this place my sincere thanks to Professor J. D. Whitney, not only for allowing me the use of his library and revising the manuscript of this essay, but also for the interest which he has constantly taken in my pursuits, and for what I owe to his personal intercourse, especially in a country where scientific communication is so extremely limited. The influence of this intercourse will, long after this, be kept in grateful memory by all those who are taking personally a part in the development of the California Academy, the members of which kindly allowed this paper to be published in their Memoirs.

THE NATURAL SYSTEM OF VOLCANIC ROCKS.

In reviewing the various attempts which have been made towards a classification of eruptive rocks —that is, those crystalline rocks made up of silicates, which, without showing themselves any traces either of stratified deposition or foliation, enter into the structure of the surface of the globe in such a way as to be unconformable with the stratification of the neighboring sedimentary rocks, and as a rule to abut against them without any gradual passage—we are struck by the observation that, if they are based on any principles at all, these are usually artificial, while none but unsatisfactory results have been obtained when the application of natural principles has been tried. This want of success is the more striking if we consider that it is peculiar to petrology, and that the efforts made in the same direction with other branches of descriptive natural sciences have been attended by extraordinary results. In zoölogy and botany, the natural system has long since been considered as the ultimate object of scientific research ; and since the time when its first outlines were discovered, the progress of these sciences has been admirable. Since then only have the developments of their different branches coöperated harmoniously towards one common end : the profoundest investigations into the anatomy of animals and plants, the study of their geographical distribution in modern time, and of their gradual development in past ages, have in their final results but been subservient to the establishment of a foundation of the natural system, and the ingenious deductions made by Mr. Darwin on the origin of species are but its philosophical interpretation. As regards mineralogy, classification was for a long time a simple enumeration of minerals, governed by certain artificial principles. A new era was inaugurated for this science by the progress of chemistry, and its application to mineralogy, by Berzelius. It led to a more correct estimate of those principles which had been formerly applied, and to the discovery of the existence of an intimate connection between crystallographical form and chemical composition. The combination of these two principles gave rise to the natural system of minerals, which since their adoption has been constantly gaining in completeness.

These are results which surpass in a surprising degree those obtained in regard to the natural classification of eruptive rocks. Even the most recent and elaborate systematical arrangements, as those proposed by C. F. Naumann, F. Senfft, B. v. Cotta, and J. Roth, though marking a conspicuous progress, are based on almost purely artificial principles. In no other branch of the descriptive natural sciences, it is true, do difficulties arise so great as those which present themselves in petrology. Prominent

among these is the entire absence of what we could call "genus," or "species," not to mention "individual." If we should succeed in discovering some natural group to which we might apply the term "family," (though even this can never be used in petrology in as definite a sense as it is in the organic kingdoms) we should find it made up of an infinite number of varieties; and if we should be able to establish several groups, the main types of which are conspicuously distinct in nature, we should find them linked together by gradual passage in chemical and mineral composition. It appears indeed utterly impossible to draw distinct boundaries between cognate groups. Certain names, such as those of granite, syenite, quartzose porphyry, trachyte, basalt and others, have been applied to designate distinct types of crystalline rocks, which can easily be recognized wherever met with. But, practically, they have to be used for larger groups of rocks, in which those distinct types appear like luminous centers, surrounded by clouds of varieties blending with each other in such a way as often to render it arbitrary whether to bring a certain rock within one or the other denomination. But there are other groups of rocks, of larger dimensions than the former, the nomenclature of which is far more indistinct, and which, in regard to classification, may indeed be said to be still in an entirely nebulous state. The vague and arbitrary mode in which different names are used for them shows plainly that difficulties in regard to them are greater than with other rocks. As will be seen in the sequel, this indistinctness of external character, as well as of designation, applies particularly (with the exception of basalt) to those rocks in the composition of which silica takes a less prominent part, while those which are richer in silica offer much more distinct characters. Most conspicuous among the names applied for the former are those of "trap," "greenstone," and "porphyry." The latter two may be conveniently used to designate groups of rocks having certain external characters in common, but as generic terms they should all be completely abolished.[1] They never convey a definite conception, as each of them is used for a great variety of rocks, and they have only too often been made to serve as a convenient cloak to cover ignorance.

The perception of these difficulties has caused the idea to be almost universally accepted, that only an artificial system of eruptive rocks can be established; that is, that classification should be made dependent on one certain principle previously as-

[1] This applies chiefly to the term "Trap," (or trapp) which had originally a definite meaning, but has gradually been extended with wonderful elasticity. It was first introduced by Torbern Bergmann for a very ancient, dark colored, augitic rock of Uddevalla, in Sweden, which is arranged in superposed layers abutting against the slope of the hill in the shape of a stairway (trappar in Swedish). This rock would be called "diabase" in modern nomenclature. The name "trapp" was then applied to other, and gradually to all, dark colored eruptive rocks, particularly to such as were found occurring in dykes; afterwards the "greenstones" (which name, too, has shown itself capable of wonderful distension) were included in that denomination; and finally it has become still more comprehensive, though not quite to the same extent with every author. Its present meaning may best be seen from the following passage by Lyell, (*Elements of Geology*, 6th Ed., 1866, p. 601 of Am. Ed.): "This term (lava) belongs more properly to that (melted matter) which has flowed either in the open air or on the bed of a lake or sea. If the same fluid has not reached the surface, but has been merely injected into fissures below ground, it is called trap." Thus, the same name which was originally applied to a distinct rock of ancient origin has been generalized so as to express now a mode of occurrence, and, what is more remarkable, a mode of occurrence the very reverse of that exhibited by the original type, which must be supposed to have been flowing on the bed of the sea, and the position of which in relation to neighboring rocks can never be explained by assuming it to have been "injected into fissures below ground." Would it not be better to drop such a name altogether?

sumed as the point of issue. Taking crystalline texture, lack of stratification as well as of foliation, and the fact of their being made up of silicates to be the characteristic features of eruptive rocks in general, the most obvious external differences among them are caused by the variations of texture and color. During the early stages of petrographical science, rocks were therefore classified on these principles. The terms trap, porphyry, pearlstone, obsidian, lava, amygdaloid, wacke, as well as greenstone, black porphyry, green porphyry, and others, are the remnants, in our present nomenclature, of that epoch when the more minute differences of rocks arising from their mineral composition were but imperfectly investigated. This principle was necessarily next in order for serving as point of issue for classification, since, as far as regards external characters, it is only second to the former in value. The emergence of petrology from a chaotic state, by the scientific application of this principle, dates from the investigation of Gustav Rose on the feldspathic minerals entering into the composition of rocks, and it has since been more generally applied for establishing subdivisions than any other. The presence or absence of quartz, the predominance among the feldspathic minerals of orthoclase, oligoclase, or labrador, the presence of augite or hornblende, are the usual points of issue, even in the most recent attempts at classification. The high value of mineralogy as a basis of classification cannot be denied. But its exclusive application has caused the combination into certain groups, of such rocks as from a geological point of view are widely separated, while it has given rise to distinctions in cases where the results of geological observation would demand close connection, as we shall have occasion to illustrate in the following pages, with reference to those volcanic rocks which are composed of hornblende and oligoclase. Gradually, those differences based on chemical composition, not capable of being detected by the eye, and the knowledge of which could only be obtained after chemistry had made the necessary advances, have become an object of scientific research. But this principle has not yet been used to any great extent for classification. It can easily be demonstrated that, when exclusively applied, it leads to a systematical arrangement of rocks which is in even greater contradiction with the natural mode of occurrence than when the same is based upon mineral composition alone, notwithstanding the fact that its great value has been conclusively demonstrated, especially by the important results which Bunsen obtained from the chemical analysis of rocks, and which mark an era in petrology. To combine granite, quartzose porphyry, and rhyolite into one class, because they resemble each other in their chemical composition, and to place them at the head of the list because containing the highest amount of silica observed among eruptive rocks, would be to take no regard whatever of geological facts. Rhyolite is, mineralogically and geologically, far nearer related to trachyte than to either granite or quartzose porphyry ; and these two are quite distinct from each other, while granite is closely allied, by gradual passage, to syenite, and quartzose porphyry to porphyrite.

It is by slow degrees only that we can hope to reach a more scientific, that is, a more natural system in this, the most intricate branch of descriptive natural sciences. The natural differs from the artificial system in this, that it starts from the application

not of one only but of various principles, compares and weighs the results obtained by each of them, and accepts them as final only when perfectly harmonizing among each other. It is then that it tries to determine what principles are most available for establishing the higher orders, and which for the subdivisions. The singular complication which is peculiar to the classification of rocks, is, besides the reasons already mentioned, due in a great measure to the fact that geology combines the double functions of a historical and an inductive science, while in petrology we have besides the requirements of a descriptive natural science. The natural system of rocks should therefore be based, not only upon the entire range of their petrographical characters, such as mineral composition, chemical composition, texture, and specific gravity, but also upon their mode of origin and geological occurrence. Classification of objects and classification of relations are, with them, closely connected, and should be made to assist each other.

The question may be raised, whether a natural system of rocks based upon such principles can be established at all, and if it can, whether it would be of any use for the advancement of science. To the first question, the answer must be in the negative, as far as sedimentary rocks are concerned. They have been formed by a complexity of circumstances, and just so complex and infinite in variety are they, in respect to chemical and mineral composition and all external characters. To analyze in detail their mode of origin, and the sources from which their material has been derived, transcends the faculty of human intellect, and it would be a hopeless task to attempt to discover any laws regulating the boundless differences of their composition. They are thus debarred from natural classification, though its principles may be applied imperfectly to the establishment of some general groups. We arrive at similar conclusions in regard to those rocks, the sedimentary origin and subsequent metamorphism of which can be proved. Accidental and local circumstances have played as conspicuous a part in their first deposition as was the case in regard to those sedimentary rocks to which the term metamorphic has not been usually applied. But as metamorphic processes of a certain nature have ordinarily affected extensive tracts of these rocks, and similarly pervaded great thicknesses of them, the local differences of their action having been apparently more in degree than in mode, they have occasioned a certain similarity of effect which partly conceals the original differences in the composition of the rocks affected ; and it appears that the differences in the kind and intensity of metamorphic action, though recognizable only in their final results, will, when better known, afford a convenient principle for a classification which may have some similarity with, but not the full requirements of, the natural system. It is different with those rocks which on the surface of the globe appear as intrusive or eruptive masses. Notwithstanding their infinite variety in character and composition, they are connected by definite relations which bring their elementary composition even within range of mathematical calculation. Their recurrence in the most widely separated countries, with similar external character, identical chemical composition, and in analogous relative order of succession, is another distinguishing feature of eruptive rocks. For these reasons, as well as in virtue of other peculiar characters

which will be more fully mentioned in other pages, they appear to owe their present positions to the action of general planetary processes, and to reveal by their own nature that of the mineral matter participating in the original composition of the globe, and by their order of succession, the mode in which the same is arranged beneath the theater of those changes which since a remote period have been taking place on its surface. Only presumptive evidence can be adduced in favor of this common and yet much disputed theory. The probability of its approximating the truth could hardly be better established by any other evidence than by the proof that all eruptive rocks of the globe, taking their historical part into account, are capable of being brought into a natural system; or, to express it more correctly, that they form among themselves a natural system, the laws of which we may be capable of discovering. Considering this in its widest bearing, as embracing all the definite correlations of eruptive rocks, and being indeed their philosophical expression, we may expect that it will make us acquainted with the history of one great feature in the development of the globe. Bearing in their own character and system the imprint of their origin, the eruptive rocks will, by their nature itself, allow well-founded conjectures as to the interior structure and composition of the earth. This, then, together with a more perfect understanding of everything connected with the agencies working below the surface of the globe, would be the philosophical use of the natural system of eruptive rocks.

Only initiatory steps can be taken at the present time towards the establishment of this system. I have confined myself in this essay to an attempt at classifying, in a way as natural as experience will allow, the "*volcanic rocks*," that is, *the eruptive rocks of Tertiary and Post-Tertiary ages*. The term "volcanic rocks," has been chosen, because the rocky matter ejected by active volcanoes belongs altogether to this class, and because almost every kind of rock, generated by eruptive activity during the period indicated, has partially forced its way through volcanic vents. We must keep the two-fold mode of occurrence of volcanic rocks clearly separated in our minds. We see them at the present day flowing from craters in the shape of lava, or being thrown out as scoria and rapilli; and there is abundant evidence that their mode of origin was very frequently the same in past ages. But in other places, it is perfectly clear that volumes of matter of the same kind have been forced to the surface through extensive fissures and accumulated above them in elongated ranges, when the origin of the outbreaks cannot be ascribed to volcanic activity. These eruptions are evidently similar in nature to those by which the greater part of the granite, syenite, or quartzose porphyry ascended to the surface in ancient times. We shall distinguish the two modes of eruptions, for the use in this present paper, as "*volcanic eruptions*" and "*massive eruptions*," and shall dwell in the sequel more fully on the difference between both manifestations and their probable causes. Then, too, the reasons will be mentioned which justify the uniting of all recent eruptive rocks into one separate class.

No other class of eruptive rocks offers greater difficulties for a systematical arrangement, as none presents throughout so great a number of varieties, and so many accidental modifications of texture and mineral composition. On the other hand, their

classification is of especial importance, as it furnishes the key for deciphering the natural system of the ancient eruptive rocks. Volcanic rocks issue from volcanic vents under our very eyes, and the record of the history of those which have originated in past ages, as preserved in their geological relations, is far more distinct than it is in regard to their ancient predecessors. No doubt exists in the mind of any observer in respect to the eruptive origin of all basalt; while in regard to granite, very different views are entertained by distinguished geologists, and supported by weighty arguments. In the former case, we have conclusive evidence, while in the second speculation has a wider scope. The knowledge of volcanic rocks will, for this reason, facilitate the correct interpretation of the nature of rocks generated in remote ages.

Volcanic rocks are widely spread over the face of the globe. It would be an object of great interest to lay down their geographical distribution on maps, and to explore the laws by which this distribution has been governed. This has been tried in regard to active volcanoes, and the importance and interest attaching to the results obtained are such as to have given rise at once to speculations as to the connection between volcanoes and other phenomena. The value of those results would be increased, if to the active craters were added the vastly greater number of those extinct volcanoes, the mode of preservation of which still allows us to recognize their former nature. Even then, however, the maps would convey but a remote idea of the general distribution of volcanic rocks; the areas comprised by which should be marked out with proper distinction of their main subdivisions. Besides an immediate bearing on more special geological questions, the knowledge of these subjects promises to be of high value for that entire department of geological science, by which the latter is most closely connected in scope with the science of physical geography. Many weighty problems, such as the causes of the present direction and extent of mountain ranges, of the outlines of continents, of the position and shape of groups of islands, of the secular oscillations of the surface of the globe, and many other questions, appear to be intimately connected with the geographical distribution of volcanic rocks and their mutual geological relations. The deduction from the latter of definite laws appears to be the initiatory step towards understanding the laws of eruptive activity of remote times, and, thereby, towards establishing a chapter in the history of the globe, which is among the obscurest and least understood.

The following classification, in which existing names are retained, as nearly as could be done with convenience, is chiefly founded on observations made in the Carpathians and in the States of California and Nevada. In respect to the variety and the distinctness of the mutual relations of the volcanic rocks, these two countries are hardly surpassed by any in which this subject has, up to this time, been scientifically investigated. Until recently, all volcanic rocks, at least those of more frequent occurrence, were comprehended in the terms: trachyte, phonolite, trachydolerite, dolerite, basalt; while, besides, separate names were used to distinguish modifications of texture, such as pumice-stone, obsidian, pearlite; or varieties somewhat more distinct in point of mineral composition, such as leucitophyre. The classification as given by Al. von Humboldt, in the fourth volume of the "Cosmos," may be considered as having represented the

most advanced stage of the science a few years ago, because it was guided by a definite principle; though when compared with contemporaneous works on petrology, it gives, on the other hand, a remarkable illustration of the great difference in the way in which the same names have been applied. Since then, the name "rhyolite" (Richthofen, Studien aus den ungarisch-siebenbürgischen Trachytgebirgen, in *Jahrbuch der K. K. geologischen Reichsanstalt in Wien*, Vol. XI [1860], pp. 153–277) has been introduced for a very distinct class of volcanic rocks. Adding this to the previous list, there results a number of names which, in geological treatises, are either grouped completely at random,[2] or in an arbitrary order, or arranged by artificial principles, when the whole classification ordinarily comprises volcanic and ancient eruptive rocks promiscuously. In order to establish a more natural system, we have, not to *make* groups, but to *find* them. Dropping all of those *à priori* principles which may be conceived having an artificial basis, we must endeavor to discover whether any great divisions are established by nature herself, and if so, of what character they are. We may then apply, as second in the order of their importance, those results which are obtained in the laboratory or geological cabinet, for defining and subdividing those groups. Most of the natural divisions which may be derived from geological observation, coincide essentially with those based on artificial principles, but are more naturally limited as regards each other. Each of them has its own more or less independent part in the architecture of mountain ranges, and a distinct geological age in reference to the other groups. Each of them comprehends a series of rocks, which, besides, are closely connected by the relations of their petrographical characters, chemical composition, texture, specific gravity, and other properties. The test of the natural foundation and general validity of these groups will be their recurrence, with mutual relations unchanged, in different parts of the globe, of which test we are never to lose sight.

The following is the classification, the approach of which to a natural system of volcanic rocks, I will endeavor to set forth in the course of this paper:

Order First: *Rhyolite.*
- Family 1. *Nevadite*, or granitic rhyolite.
- " 2. *Liparite*, or porphyritic rhyolite.
- " 3. *Rhyolite proper*, or lithoidic and hyaline rhyolite.

Order Second: *Trachyte.*
- Family 1. *Sanidin-trachyte.*
- " 2. *Oligoclase-trachyte.*

---

[2] That this is even done in books of the highest standard, may be seen by reference to one so prominent as *Lyell's Elements of Geology.* The following is the order of names of which, under the head of "volcanic rocks," definitions are given (p. 592, pp. of 6th Am. ed., 1866): Basalt, augite rock, trachyte, trachytic porphyry (in connection with which the name "andesite" is mentioned), clinkstone, greenstone, porphyry, amygdaloid, lava, scoriæ or pumice, volcanic tuff or trap-tuff, agglomerate, laterite.

Order Third: *Propylite.*
Family 1. *Quartzose propylite.*
" 2. *Hornblendic propylite.*
" 3. *Augitic propylite.*

Order Fourth: *Andesite.*
Family 1. *Hornblendic andesite.*
" 2. *Augitic andesite.*

Order Fifth: *Basalt.*
Family 1. *Dolerite.*
" 2. *Basalt.*
" 3. *Leucitophyre.*

Order First—Rhyolite.

The name "rhyolite" was proposed, early in 1860,[3] for certain rocks frequently occurring on the southern slope of the Carpathians, and distinguished, in mineral character, from trachyte, which they otherwise resemble, by the presence of quartz as an essential ingredient, and an almost infinite variety of texture. Beudant[4] had, long before, described certain varieties of these rocks as *porphyre trachytique*, pumicestone, pearlite, etc. In 1861, the name "liparite" was proposed by J. Roth[5] for rocks of similar nature occurring on the Lipari Islands. The term "rhyolite," however, being of prior date, has since been almost generally adopted, among others by F. v. Hochstetter, for rocks from New Zealand, by C. Peters, G. Stache, and others for those of Hungary and Transylvania, by Ferd. Zirkel for those of Iceland, by B. v. Cotta as a general term in his "*Gesteinslehre.*" The word "rhyolite" is designed to express one of the prominent features of these rocks. It is this: that their chief varieties have the appearance, as it were, of natural glasses, and bear evidence, more than any other rocks do, to the unpracticed eye, of having been flowing in a viscous state.

Mode of Geological Occurrence.—Rhyolite has had its distinct epoch of eruption in relation to other volcanic rocks. Wherever it occurs it may be easily proved to have been of more recent origin than either propylite, andesite, or trachyte, but to have preceded basalt in age. As to its geographical distribution, it is confined to the immediate neighborhood of one or all of those antecedent rocks, and occurs ordinarily within their very limits. Until lately, not much attention had been paid to it. But since the establishment of the name, rhyolite has been found to be widely distributed, though always occupying a subordinate position. In Hungary it usually skirts the lower part of the flanks of andesitic ranges, forming hillocks and ridges of little elevation, filling depressions, and issuing in currents from fractures, and, in general, giving evidence of its entire dependency on the places of previous eruptions. The greater portion of the rhyolite has, in that country, been evidently ejected by volcanic activity. It appears that the same may be said in regard to the

[3] Loc. Cit. [4] Voyage en Hongrie. Paris, 1820. [5] J. Roth, die Gesteins-analysen. Berlin, 1861.

rhyolitic rocks of New Zealand, St. Paul, and Iceland. But it has not been so generally the case on the western coast of America. The volcano of Lassen's Peak, and the environs of Mount Helena, in California, present grand instances of a volcanic origin of rhyolite. But in the adjoining State of Nevada it appears to have been extensively brought to the surface by massive eruptions. It is of unusually frequent occurrence along the eastern slope of the Sierra Nevada, and farther east in the Great Basin. Ranges of hills are there completely built up of rhyolitic rocks, not always in as close proximity to such as are antecedent to them in age, as is the case in the Carpathians.

It is one of the characteristic features of rhyolite, that it presents, more than any other rock does, signs of having been in a state of what Daubrée has called "aqueous fusion," or the fusion of its mass by solution, under great pressure, in superheated water. Another peculiarity is the circumstance that the eruptions of rhyolite, whether massive or volcanic, bear evidence of having been generally accompanied by extremely violent solfataric action, which probably surpassed, on an average, that connected with the ejection of other volcanic rocks. This action appears to have been one of the chief agents in the formation of the rich silver-bearing veins of Hungary, as well as of some in Mexico, and to have also been peculiarly characterized by the occurrence of an unusually large amount of fluorine and chlorine among the escaping gases.

Mineral Composition.—Rhyolite may be concisely defined as trachyte with an addition of silica, not chemically combined, and which is either segregated into crystals of quartz, or dissolved in the rock, and then no longer recognizable to the eye. It is, owing to the high proportion of silica entering into its composition, the representative of granite among volcanic rocks. Chemically, it is its complete counterpart, as far as ascertained by analysis, and even in outward appearance certain varieties of rhyolite offer at first sight a striking similarity with granite, though closer observation will at once reveal well marked differences between both. Rhyolite outrivals any other rock in respect to the truly astonishing number of its varieties, which are chiefly occasioned by modifications of texture. It consists in general of a paste, with or without minerals enclosed.

The paste, chiefly, is liable to variation. Its colors are: white, gray, yellow, green, red, brown, which occur in all manner of shades; light ones prevail, while perfect black has not been met with. The texture is as varied as the color. First are to be noticed a number of hyaline varieties, which are represented by obsidian, pumice-stone, and pearlite, and the frequent occurrence of which is a peculiar feature of rhyolite. Though associated with volcanic rocks of every composition, these natural glasses, as they may be called, decrease in relative quantity and variety with the decrease of silica.[6] Obsidian when having the composition of rhyolite, offers little

[6] There is no better example of the artificial principles on which the classification of rocks has usually been based than the fact, that accidental modifications of texture, which appear to result chiefly from the difference of the conditions attending either the fusion or the cooling of the mass, have been considered as of equal value with other differences of the greatest importance; and pumice-stone, trachyte, basalt and pearlite have been considered as coördinate subdivisions, even long after classification had been made dependent chiefly on mineralogical principles.

difference in character from that which is a modification of other volcanic rocks. In regard to pumice-stone, however, Abich has proved that when formed of the material of trachyte or andesite it has rounded pores, and ordinarily a green tint; while those varieties which have the composition of rhyolite, excel by the elongated and irregular shape of their cavities, which are enclosed in a fine tissue of fibres of silken appearance and white color. Between both kinds of pumice-stone there are gradations apparently dependent as to their character on the amount of silica entering into their composition. Pearlitic texture is peculiar to rhyolitic rocks. From these more or less perfectly glassy varieties there are gradations to the texture of enamel and porcelain, and to a certain cryptocrystalline texture very frequent among volcanic rocks in general, and for which we may apply the obsolete term "lithoid." This passes into the microcrystalline, and always more or less vesicular, texture of trachyte.

The paste constitutes occasionally alone the substance of the rock. But these instances are rare. More frequently it contains enclosed mineral substances differing from it in nature, and in a few instances these accumulate to such a degree as almost to exclude the paste. Quartz is of the most general occurrence among those which are crystallized. Sanidin is its almost unfailing companion. Oligoclase, usually of a vitreous variety, and black mica, are, too, among the usual ingredients, while hornblende is generally less conspicuous. Besides these minerals, there are two substances entering accidentally into the composition of rhyolite, which are, however, among the characteristic features of the rocks of this order. One of them consists in small globular grains, from the size of a pin-head to that of a rifle bullet, called "sphærolites" by Beudant. They have a radial structure, and contain ordinarily a small crystal of feldspar in the center. Certain hyaline, and, in a greater measure, lithoid varieties of rhyolite contain them in large quantity. They occur also, though less frequently, in other natural glasses not of rhyolitic composition, and may be produced artificially, by allowing molten glass to cool very slowly to what is known by the term "Réaumur's porcelain." The second formation frequently met with in rhyolitic rocks are the "lithophysæ," consisting in larger and smaller cavities filled by a substance strangely inflated by some gaseous evolution which apparently originated in the matter itself (Richthofen, l. c.). They constitute sometimes nearly the entire mass of the rock.

The endless varieties of rhyolite appear to be due to the susceptibility of the fluid mass to be influenced by accidental circumstances to which it may have been exposed, partly before being ejected, and partly during the process of solidifying. A considerable influence, which, however, has not yet been investigated, is probably exercised by the difference in the amount of water which entered into the composition of the molten mass, and partly expanded to steam in the instant of ejection. The vesicular inflation proper to trachytic texture, the spongy inflation of pumice-stone, and the concentric separation of infinitely fine laminæ, as is often shown in perfect pearlitic texture, are probably three different modes of manifestation of one slightly varied cause, which may most likely be found in the conversion of water into steam, which participated in the composition of the molten mass.

Difference of Rhyolite from other Rocks nearly related to it.—Several varieties of rhyolite bear so close a resemblance to other rocks, that some mention must be made of their distinguishing features. Rhyolite may be easily distinguished from granite. The varieties by which it mostly approaches the same are those which contain crystals of quartz, feldspar and mica in unusually large proportion and size. But in the case of rhyolite, the paste in which they are imbedded is never wanting. Moreover, the orthoclase and oligoclase are of the vitreous varieties, and quartz is present either in crystals or in rounded crystalline grains, while in granite it usually permeates the interstices between the other component minerals. Much closer is the affinity which certain other varieties of rhyolite bear to quartzose porphyry, especially those which have a paste of homogeneous appearance containing no crystals but those of quartz inclosed. Geological observation will never fail, in such instances, to establish the nature of the questionable rock, as it will show its association either with true rhyolite or with true porphyry. The same test has to be applied occasionally with respect to some other varieties which contain the silica equally diffused through the paste, and bear a close resemblance to trachyte. In this instance, however, even geological observations will sometimes fail to determine the exact position. There is a gradual passage in character between every two nearly related rocks, such as rhyolite and trachyte, or granite and syenite, and it frequently happens that either name may be used with equal right.

Subdivisions.—In establishing the subdivisions of most orders of eruptive rocks, mineral composition affords a principle, not only the most convenient for practical application, but one that answers well the requirements of the natural system, when made subordinate in value to those higher principles which determine the limits of classes and orders. In the case of rhyolitic rocks, however, it is not as applicable as in that of other orders. They should, from this point of view, be subdivided into those which contain quartz and those which are devoid of it, or into such as carry sanidin and such as contain both sanidin and oligoclase. But, since rhyolite of any certain chemical composition may contain its surplus of silica, either visibly segregated in crystals of quartz, or dissolved in the mass of the rock, and as the case may be similar in regard to the occurrence of either species of feldspar, the application of this principle would lead us to combine into one group quartzose rocks differing considerably among themselves as to the proportion of silica they contain, while another group might comprehend rocks of virtually the same nature as those of the first, and differing from them only accidentally in external character. More natural subdivisions of rhyolitic rocks are obtained by taking as a basis of classification their difference in texture, which either approaches, to a certain degree, that of granite or is porphyritic or hyaline. It is a singular fact, and one difficult of explanation, that rhyolite, at every place where it has been hitherto observed, presents, either solely or chiefly, one of those three modes of texture. Lassen's Peak, for instance, presents the granitic variety almost exclusively. Sonoma, in California, and the Tokay Mountains in Hungary, only the hyaline, and other places exclusively the porphyritic varieties. This circumstance, which is peculiar to none but rhyolite among eruptive rocks, indicates the

dependency of the mode of texture upon deep-seated influences which acted at the very source of the eruptive matter, and produced a certain molecular condition of the latter, varying at each locality. Some light on this subject may be expected from minute geological observation, accompanied by exact chemical and microscopical researches.

The following are the subdivisions which may be distinguished in regard to the texture:

Fam. 1st. Nevadite or Granitic Rhyolite.—The name "Nevadite" is derived from that of the State of Nevada, where these rocks have been first met with in larger accumulations. The local derivation may answer in this instance, as granitic rhyolite is little known from other countries, excepting the neighboring California. In the Carpathians, it occurs isolated in Transylvania, but by no means as characteristic as in Nevada. The name "granitic rhyolite" is designed to indicate the general resemblance of these rocks to granite, which is conspicuous in boulders, or on large exposed faces, but disappears on closer examination. It is chiefly produced by the similarity in color, which is of light shades of gray and red in Nevadite, and by some affinity in mineral composition. Nevadite contains crystals of quartz in large proportion; the corners are usually rounded, and the quartz itself cracked, like glass when rapidly cooled. Sanidin occurs in crystals of larger size than oligoclase, sometimes of an inch in diameter. The crystals of both are often cracked throughout their mass, and rounded at the corners. Black mica and hornblende are ingredients of frequent occurrence. These minerals are, in more or less quantity, enclosed in a paste which is probably a partially microcrystalline, and partially amorphic aggregation of the same ingredients, and has a highly vesicular texture, rendering it rough to the touch, even more so than is the case with trachyte. Geologically, Nevadite appears to have been produced as frequently by volcanic activity as by massive eruptions. An interesting occurrence is that at Lassen's Peak, in California, where it was discovered by Prof. W. H. Brewer and Mr. Clarence King.

Fam. 2d. Liparite, or Porphyritic Rhyolite.—The name "Liparite," which was proposed by J. Roth for this whole class, may be conveniently retained for those varieties of rhyolite which approach quartzose porphyry in character, as they appear to occur on the Liparic Islands, either solely or at least in larger proportion than other varieties. They consist of a paste which has a similar texture to that of quartzose porphyry, and incloses crystals either of quartz only, or of quartz and sanidin, or of quartz, sanidin, oligoclase, and black mica, or of one or both kinds of feldspar, without quartz being present. The crystals have sharp corners and are seldom cracked; oligoclase is rarely of the vitreous variety. Typical varieties of the rocks of this family occur largely in the hills of Bereghszasz in Hungary.

Fam. 3d. Rhyolite proper, or Hyaline Rhyolite.—The extensive range of varieties afforded by all manner of modifications of hyaline texture are a peculiar feature of rhyolite, distinguishing it from any other eruptive rock. In outward appearance they remind one of artificial glasses cooled under the most varied conditions. *Obsidian, pumice-stone*, and *pearlite*, constitute but a small portion of the varieties occurring;

others resemble enamel and porcelain, or present appearances which are difficult to describe. The occurrence of sphærolites and lithophysæ add to the variety of their aspect. Another feature peculiar to the rocks of this family consists in a foliated structure, the folia being often thinner than paper, and presenting an endless variety of color and modifications of texture. Pearlite alone does not participate in the peculiar form of foliated structure.

All these varieties again contain, enclosed, all the different minerals before mentioned, or only a few of them, or they enclose no foreign substances at all. The rocks of this family are chiefly of purely volcanic origin, but in some instances currents of them appear to have been ejected through crevices in the older volcanic rocks.

Order Second—Trachyte.

The name "trachyte" was first used by Hauy, in his academic lectures, to designate the well-known volcanic rocks composing the Drachenfels on the Rhine. But it did not come into general use, until Beudant, the pupil of the former, introduced the name into geological literature, by his justly celebrated work "Travels through Hungary," a book which abounds in sagacious observations on the subject of volcanic rocks. Beudant extended, however, the application of the name over a much wider range than his teacher had done. Several years later, in 1835, L. v. Buch introduced into literature the name "andesite," designating by it certain dark-colored rocks, which were then known, especially through the collections of Al. v. Humboldt and Boussingault, to enter largely into the composition of the volcanic portions of the South American Andes. These rocks, which form obviously a part of those which Beudant had comprised under the name "trachyte," were supposed to be particularly distinguished by containing a peculiar species of feldspar which Abich (in 1840) called "andesine." When, however, a few years later, this mineral was no longer considered to be a separate mineralogical species, and its name was dropped, that of "andesite" became obsolete with it, notwithstanding its prior origin. Thenceforth, the range of the varieties of volcanic rocks comprised in the term "trachyte" has been even more enlarged than Beudant had proposed in his dissertation. Eruptive rocks, widely differing in nature—in fact nearly all those of tertiary and post-tertiary age, with the exception of basalt—have been united in it. But by no author, probably, was the application of the name as much extended as by Al. von Humboldt.[7] On the other side, however, he was the first, by the establishing of numerous subdivisions, to draw attention upon the necessity of using separate names for more limited ranges of varieties. Recently, B. von Cotta, J. Roth, and others, have tried to demonstrate, how little reason there had been for dropping the term "andesite." They re-introduced it into petrology; but, in drawing the limits between andesite and cognate groups by principles of artificial classification, they used the name in a sense differing to some extent from that in which it has been applied in the following pages.

[7] Cosmos, vol. iv. The first four orders of trachyte were proposed by G. Rose, the other two were added by Humboldt.

There is plainly indicated, from a geological point of view, the existence of two large groups within the limits of Beudant's "trachyte." The two existing names, "trachyte" and "andesite," may conveniently be used for their designation, since those rocks, for which either of the two names was first introduced, are indeed the types of the two natural groups.

Mode of Geological Occurrence.—The trachytic rocks have had their independent epoch of eruption in every volcanic country. They preceded rhyolite and basalt in age, and were posterior to the ejection of propylite and andesite. The trachytic epoch was usually of long duration. In many localities, its later part blended with the earlier of the rhyolitic epoch, which is manifest by the alternate emission of trachytic and rhyolitic matter, during that time which was intermediate between the epochs of the ejection of the principal bulk of either of them. As regards geographical distribution, trachyte is as much dependent upon, and as closely allied to, the preëxisting masses of propylite and andesite, as is the case with rhyolite. It towers up in peaks, cones, and ridges, which are distinguished by their rugged outlines, and rest, in the majority of cases, upon the summits or the flanks of the ranges composed of those older volcanic rocks. But there are also numerous instances when these may be seen to be accompanied, at some distance, by trachytic outbursts, when a cursory examination might make the latter appear to occupy an independent position. Trachyte does probably not compose, by itself, any extensive mountain ranges, and it remains, in general, greatly inferior in bulk to andesite. In Europe, its outbreaks were scattered and isolated, and, though they have been quite numerous, the aggregate quantity of trachytic rocks is not considerable. They occur in Hungary and Transylvania, on the Lower Rhine, in Central France, in the Grecian Archipelago, and in other parts of that continent, as well as in the adjacent portions of Asia. Specimens of trachyte, owing to their beauty and varied aspect, are usually much more numerous in geological cabinets than those of andesite—a fact which has frequently occasioned some misconception regarding the relative proportion and importance of trachyte and andesite among volcanic rocks.

In the structure of the North American Andes, trachyte takes a more important part than in Europe. A continuous range of it, at least ten miles in extent, and forming rugged crests, encircles the Washoe Mountains to the east, in the shape of a crescent. Trachyte rests there on propylite, and its ejection has probably had an intimate connection with the formation of the Comstock Lode. Other accumulations of similar extent may be noticed at Esmeralda, on the eastern slope of the Sierra Nevada, around Red Rock Cañon, south of Walker's Pass, in the surroundings of Lake Tahoe and Sierra Valley, and at other places east and west of the Sierra Nevada. In the northern provinces of Mexico, trachyte is known to occur quite extensively. At all the places mentioned, the greater part of its bulk bears evidence of having been brought into its present position by massive eruptions, while traces of extinct trachytic volcanoes are scarcely wanting at any of them. Trachyte is still being ejected by a number of active volcanoes. Among them may chiefly be mentioned those of Central America, the greater part of the modern lava of which has been proved to have the chemical and mineral composition of trachyte.

Mineral Composition.—Trachyte is only inferior to rhyolite in the number of its varieties. Yet its chemical composition is as simple as that of the latter, and ranges within as definite limits. The rock appears to contain, on an average, from 60 to 65 per cent. of silica, and is in this respect, as in others, next allied to rhyolite. The difference between the rocks belonging to both orders, having its fundamental cause in the chemical composition, manifests itself externally in certain differences of character, among which may be mentioned: the absence of quartz among the essential ingredients of trachytic rocks, which probably contain no free silica at all; the usual predominance in them of oligoclase over sanidin; the larger proportion in which hornblende participates in their mineral composition, and the fact of their specific gravity exceeding that of rhyolite. Like almost all volcanic rocks, trachyte consists of a paste in which are imbedded various crystallized minerals. This paste is of various colors, and has usually a more or less vesicular texture, which, by its property of imparting to the rock a certain roughness of touch, gave origin to the name. Chief in order among the enclosed minerals are sanidin, oligoclase, mica, and hornblende. They vary considerably as regards their relative proportion, and therefrom arises a number of varieties which have been partly distinguished by separate names. More numerous varieties, however, are occasioned by the differences of texture. Pumice-stone is of frequent occurrence among the latter, but it never exhibits that perfect long-fibrous and silken nature peculiar to it when being a variety of rhyolite. Obsidian, in different grades of perfection, is no unusual modification of the trachytic masses, and it is often filled with sphærolites, while no pearlite has yet been found having the chemical composition of trachyte. Foliated structure may frequently be met with; but the folia are not of that exquisite fineness which is peculiar to those of rhyolite. The modes of texture which alternate in the folia, are chiefly obsidian, pumice-stone, and microcrystalline varieties.

Subdivisions.—It appears that two natural groups of trachytic rocks may be distinguished, which differ at the same time, from a mineralogical and chemical point of view, and have therefore been arrived at similarly by the application of artificial principles.[8] We distinguish with B. v. Cotta:

[8] I may here remark that I have endeavored to retain existing names, as much as possible, for designating the orders and families distinguished in this present classification. What I have tried to establish as natural groups, may therefore, on account of the similarity of nomenclature, coincide apparently, in many cases, with the groups established by artificial principles, and named in accordance with them. The former do indeed coincide in a few instances with the latter; but in the majority of cases, the limits of the application of the names differ widely when established from the two points of view mentioned. It would require too much space to go into detail on this point in regard to every name. I will, therefore, confine myself to an illustration regarding the order of trachytic rocks. B. v. Cotta, (with several other authors) unites under the name of oligoclase-trachyte all volcanic rocks consisting chiefly of hornblende and oligoclase, with the exclusion of certain dark-colored rocks, to which he applies the name andesite. The former name, if used in the meaning of that author, comprises, therefore, our order of propylite, together with all those rocks for which the term oligoclase-trachyte has been here applied. It is evident, from the different geological positions occupied by propylite and trachyte, as well as from the distinct petrographical character which either of them exhibits when occurring in large accumulations, how much their union would be opposed to a correct representation of natural relations. It is obvious, besides, that the union is unpractical. It would actually prevent the possibility of a clear and simple geological description of those countries in which propylite and trachyte occur together with other volcanic rocks. The distinction between both is so great that it has scarcely ever failed to be noticed by unbiased observers in those localities where both rocks occur. To unite them because

Fam. 1st. *Sanidin-trachyte.*—The color of the paste varies, but it usually presents light shades of gray, reddish, and reddish-brown; its texture exhibits all the varieties mentioned. There are imbedded in it: crystals of sanidin, or of both sanidin and oligoclase, besides mica and hornblende; the latter, however, is frequently wanting. To this family belong the rocks which compose the trachytic ranges of Washoe and Esmeralda, that of the Drachenfels, and many others.

Fam. 2d. *Oligoclase-trachyte.*—The paste is of the same color as in the rocks of the first family, though darker shades prevail, and presents a similar variety of texture. Imbedded are, chiefly, crystals of oligoclase and hornblende, the former being frequently of the vitreous variety; the latter having usually the shape of broad needles, with a black color and bright cleavage-planes. Besides those minerals, black mica is of frequent occurrence. The rocks of this family are ordinarily associated with those of the first subdivision, but in some localities are not accompanied by them. At Lassen's Peak there is but one limited space where rocks of both families intermingle; it is near the place where the lava has been ejected. Apart from it, the grand currents of lava, extending to from ten to twelve miles distance from the place of ejection, consist merely of oligoclase-trachyte. To this family belong those varieties of trachyte which were called "domite" by L. v. Buch.

The fact that the occurrence of the rocks of either one of these two families will frequently exclude those of the other, and that, even in those localities where they are associated together, they will occupy separate places in regard to geological superposition, appears to indicate that the distinction of these two subdivisions forms an approach to the requirements of the natural system.

Order Third—Propylite.

The rocks of this order have hitherto occupied a very undecided position in the different classifications of rocks proposed, and just as various has been their nomenclature when they had to be mentioned in geological descriptions. The fact that they bear close resemblance in mineral character to ancient diorite, while, geologically, they are intimately allied to volcanic rocks, has been the principal cause of this uncertainty of their position. In Hungary and Transylvania, they occur quite extensively, and, being of practical importance as the bearers of rich metallic veins, have had to be noticed frequently in treatises on the mines of those countries. Beudant applied for them the name "porphyric greenstone," and classified them, along with syenite, among

they are both chiefly composed of oligoclase and hornblende, would render it indeed, practically, a very difficult and complicated task to compare the geological relations of different volcanic countries on the strength of written descriptions. If we now follow the classification of J. Roth, we find the application of the name trachyte limited to those volcanic rocks which contain sanidin, but are devoid of quartz. All those numerous varieties which do not contain sanidin, but are intimately allied to sanidin-trachyte, by their mode of geological occurence as well as by their physical characters, are excluded from the denomination, and, together with all volcanic rocks composed chiefly of hornblende and oligoclase, are united into one subdivision of andesite. The reasons which justify the separation of the compounds of oligoclase and hornblende into three different groups, (oligoclase-trachyte, hornblendic propylite, and hornblendic andesite) will be detailed in the following pages. It may then be understood why the adoption of the different systems of the current nomenclature would render the concise geological description of volcanic countries extremely difficult, and would conceal the harmony really existing in the relations which they present in different countries.

the "transition rocks." Since then, the names greenstone, greenstone-porphyry, diorite, dioritic porphyry, and others, have frequently been applied for the same rocks of the Carpathians. Similar names have been used for them when they were mentioned as occurring in other countries, as for instance Mexico, where still oftener they have been simply styled "porphyry." In 1860, having had sufficient evidence of the Tertiary age of these rocks and their close connection with the volcanic rocks of that period, I separated them, in a treatise on some volcanic countries in Hungary, already referred to, by the name of "greenstone-trachyte," from the remainder of those rocks which then were usually comprehended by the name trachyte. That designation has since that time been frequently applied in geological descriptions. The attempts made to classify the rocks included in it have, however, been rather unsuccessful. J. Roth combines them into one group with amphibol-andesite, from which they are quite distinct as regards their petrographical as well as their geological properties; while others considered them as belonging to the dioritic rocks. The grounds upon which they have been united with the latter are purely artificial, since diorite is, from a geological point of view, widely separated from "greenstone-trachyte." Breithaupt established a new name, "Timacite," for a variety of our propylite, which is of very limited occurrence, and in which he discovered a new variety of hornblende, called by him "gamsigradite." Most valuable contributions for the knowledge of our "propylite," were recently given by Dr. Guido Stache, from observations made in Transylvania. (Hauer and Stache, Geologie Siebenbürgens, Vienna, 1863.) He discovered the occurrence, in that country, of quartz-bearing varieties in greater extent than they have been found hitherto at any other place. Stache retains the name "greenstone-trachyte," for those varieties which contain no quartz, and proposes the name "Dacite" (from the Roman province of Dacia to which Transylvania belonged) for those of which quartz is a common ingredient.

These statements will show the discrepancy of the views which have been entertained in regard to the systematic place and the nomenclature of the rocks under consideration. It is owing, partly to their twofold affinity with other rocks, (mineralogically to diorite, and geologically to volcanic rocks) and partly to the fact that they had, until lately, not been made the object of study. All observations made during the last few years concur in this, that those rocks, wherever they have been encountered, form a distinct link in the range of Tertiary and Post-tertiary eruptive rocks, being everywhere the first of them in age, while they are, in regard to their mineral character, no less distinct from any other eruptive rocks originated in those periods. They constitute, indeed, a more natural and more distinct group than any of the other volcanic rocks, and it has become desirable to unite them under a common designation. As no prominent property distinguishes them from diorite, and the derivation of the name from one certain locality did not appear proper for the designation of rocks of wide distribution, geological relations alone could be used as a basis for the nomenclature. The rocks under consideration, as we shall hereafter more fully develop, give evidence, in all localities where they have been met with of having reopened the eruptive activity after ages of comparative repose. It is since then only,

that this activity has continued with extreme violence over all parts of the globe, through the remaining part of the Tertiary and the Post-tertiary periods, growing, however, more and more faint during the latter. Propylite was, in fact, the precursor of all other volcanic rocks, and its appearance on the surface inaugurated a grand revolutionary activity on the globe. It is this position, at the entrance as it were to a new era in the history of the earth, which has given rise to the name "propylite."

Mode of Geological Occurrence.—The position of propylite at the bottom of all volcanic rocks is its most important geological feature. Its age has in no instance been ascertained with exactness. The nearest approach to its determination was made in Northern Transylvania, where I found, in several localities, nummulitic strata intersected by dykes and large intrusive masses of propylite, and covered by accumulations of it. As the greater part of the volcanic rocks in that country are of Miocene age, the ejection of propylite must have taken place either in the latter part of the Eocene or in the earlier part of the Miocene epoch. In view of the facts, that volcanic rocks have nowhere been observed to be anterior to the Eocene (probably even not prior to the Miocene) epoch, and that propylite is always allied to them as the first link in the order of succession, it may be inferred that propylite is, in general, of Tertiary age, until proofs to the contrary may be found.

The forms of propylitic mountains can be observed only in rare instances, since they are usually covered by other volcanic rocks, especially by andesite. This circumstance may also explain the fact of the comparatively rare occurrence of propylite as a surface-rock. In the environs of Bisztritz, in Northern Transylvania, it forms several high, isolated cones with steep slopes, resting on Eocene strata; their fine, dome-shaped appearance is scarcely surpassed in beauty by that of any other kind of rock. No estimate can be made in regard to the relative bulk of propylite which has been ejected, on account of its being overlaid by andesite and trachyte. It occurs, as far as exposed to view, in quite considerable accumulations, at Nagybanya and Kapnik, in Hungary, in Washoe, and at Silver Mountain, and covers large areas in Mexico, where it overlies the Cretaceous. It appears to have been profusely ejected through fissures, and its emission not to have been accompanied by volcanic action proper; no distinct traces, at least, have been found of propylitic volcanoes. Massive eruptions are known to have occurred, besides the places mentioned, in several other parts of the southern slope of the Carpathians, on the highlands of Armenia, and in Mexico, while the occurrence of propylite in Bolivia, the Altai Mountains, Northern China, and some other countries, may be inferred from the description of their geology.

Propylite has been repeatedly considered to be a sedimentary rock, metamorphosed *in situ*. The cause of this opinion was probably the fact that there are rocks which undoubtedly have had that mode of origin, and share with propylite the resemblance in mineral character to diorite. The eruptive origin of propylite is, however, evident, as it intersects stratified rocks in the shape of dykes. In Washoe and Silver Mountain, moreover, there are extensive accumulations of propylitic breccia and stratified tufa. The latter consists of alternate layers of coarse conglomerate, fine-

grained propylitic detritus and massive propylite, and the entire system is intersected by dykes of the latter.

A particular interest, which has a practical bearing of some importance, attaches to propylite, inasmuch as, notwithstanding its limited occurrence, it yields probably a larger amount of silver than any other rock. Several of the principal silver-bearing veins, as the Comstock vein in Washoe, the celebrated veins in Hungary and Transylvania, as well as some of those in Mexico, and probably too in Bolivia, are enclosed in propylite.

Mineral Composition.—In propylite are united the petrographical properties of ancient dioritic rocks with those of andesite and oligoclase-trachyte. Varieties are numerous, but produced more frequently by the difference of the component minerals in size and relative proportion than by the texture, which remains porphyritic in every instance. The most common varieties consist of a fine-grained, microcrystalline paste of dark green or greenish brown, more rarely of reddish and dark gray colors, in which are imbedded crystals of oligoclase and hornblende; the former is of whitish or light green color, the latter ordinarily dark green and fibrous, seldom black with bright cleavage-planes (as is the case with gamsigradite). The paste appears to be a fine-grained aggregation of the same two minerals (the feldspathic ingredient prevailing), with the admixture of titanic iron, and to owe its ordinarily green color to the profuse dissemination of small particles of green, fibrous hornblende. Sporadic crystals of augite are occasionally met with in some of the common varieties, while others contain rounded grains of quartz sparsely enclosed. Recent observations have led to the discovery of two series of varieties deviating from the usual composition as explained. One of them is produced by the increasing proportion of the grains of quartz; the other by the more profuse occurrence of augite. The former was found by Stache, in Western Transylvania; the latter observed by me at Silver Mountain. Both appear to be of a limited geographical distribution, but are of great interest, as they extend the limits of the order of propylitic rocks, without rendering either their petrographical character, or their geological relations less distinct. In regard to the latter, it may be stated that the entire range of the quartzose to augitic varieties was anterior in age to andesite.

Difference of Propylite from other Volcanic Rocks nearly related to it.—The rocks of two other orders have an affinity to propylite, namely oligoclase-trachyte and andesite. The principal ingredients of either are hornblende and oligoclase, and either of them contains crystals of both these minerals imbedded in a paste. Yet there is a notable difference in character between these two, as well as between either of them and propylite. It is so conspicuous to the eye that the respective rocks have ordinarily been distinguished in geological descriptions, even in those of older time; and even the unprofessional eye would be able to distinguish the three groups in a collection of specimens belonging to them. Yet, it escapes description. It may, at this present time, safely be founded on what the botanist would call "habitus," a certain general character which it is as easy to recognize by the eye as it is difficult to describe it in words, and impossible to define its causes. It is probable that observations, such

as Sorby has made in reference to those minute differences of texture, which can only be detected with the aid of the microscope, and H. Rose in regard to the modifications of silica and their causes, aided by exact chemical analysis and experiments made with the view of enquiring into the differences of origin of such eruptive rocks as differ from each other in texture, will, if further prosecuted, reveal the true nature and cause of the properties which distinguish the rocks of these three different orders.

A few of the more palpable differences may here be noticed. Propylite is essentially of greenish color, and some of its varieties resemble diorite in composition and texture; andesite is of blackish color and approaches basalt in aspect; trachyte is of various colors and shades, among which green and black are rarest of occurrence, and in regard to its external characters resembles rhyolite more than any other rock. Oligoclase, in trachyte, is frequently of the vitreous variety, scarcely ever so in propylite and andesite. Hornblende is an essential ingredient in these two, not so in the former; it is of fibrous texture and green color in most varieties of propylite, black in andesite and trachyte. Mica is seldom wanting in the latter, while it is not of common occurrence in propylite and andesite. Titanic iron enters largely into the composition of these, and is contained in smaller proportion in trachytic rocks. The latter excel by having the greatest variety of texture, while propylite has among the three the most perfect porphyritic texture, which has given rise to its frequent popular designation "porphyry;" this name has never been applied to andesite or trachyte.

The enumeration of all these trifling differences is, however, insufficient to express the marked distinction which exists in the external characters of propylite, trachyte and andesite. As a similar, and even more conspicuous, distinction manifests itself in their geological relations, we have to consider the existence of those three natural orders as a fact founded on observations, although we may be utterly unable to explain, and even to express it in words.

Subdivisions.—The remarks made in regard to the mineral composition of propylite have shown that the range of its varieties may conveniently, and in harmony with geological occurrence, be subdivided into three parts:

Fam. 1st. Quartzose Propylite or *Dacite.*—This embraces rocks which, though having in general a similar composition to those of the following family, contain besides, rounded grains of quartz, sometimes in considerable proportion. They occur in the western part of Transylvania, where their outbreaks succeeded those of rocks of the second family, and preceded those of andesite.[9] Similar rocks have been observed in Sinaloa (Mexico).

Fam. 2d. Hornblendic Propylite.—Rocks composed chiefly of hornblende and oligoclase, as described above. This family embraces vastly the majority of all propylitic rocks observed, among others those of Washoe. Breithaupt's "timacite" is one of its varieties.

[9] Fully described by G. Stache, loc. cit.

Fam. 3d. Augitic Propylite.—Rocks distinguished by the accession of augite among the ingredients of the rocks of the foregoing family. It is present in greater or less quantity, sometimes predominating over the hornblende. To this family belongs the propylite of Silver Mountain, which contains augite in larger proportion than any other known variety.

Order Fourth—Andesite.

The history of the name "andesite" has been noticed conjointly with that of "trachyte." At the time when the former name was first proposed for certain rocks of the Andes, a few specimens of which had been brought to Europe, it was intended as a designation of an accidental variety, proper to that mountain range. But those same specimens have proved since to be the type of one of the most important groups of volcanic rocks, which is distinct from others in character, and has a wide distribution.

Mode of Geological Occurrence.—Andesite vies with basalt in regard to the quantity of matter ejected to the surface, and probably excels the same in this respect. In most of those parts of the Andes, in regard to the geology of which we possess reliable information, it forms the chief bulk among volcanic rocks. The same is the case on the southern slopes of the Carpathians, at Nangasaki in Japan, and on the islands of Luzon and Java. Andesite succeeded the ejection of propylite, and prepared the way to that of trachyte. Preëminently the greater part of it has, to all appearance, been ejected through extensive fissures; that is, it has been produced by what we styled massive eruptions; though andesitic volcanoes, too, are not of rare occurrence, and, including those which are extinct, appear to have been particularly grand in their activity. It may be supposed that many of the former craters have been destroyed. Andesitic mountains are characterized by monotony in scenery. They form continuous ranges, which are often of considerable elevation and extent, but exhibit gentle outlines in their summits as well as in their slopes. Breccias only, which accompany the solid rock ordinarily in vast quantities, cause local interruptions of the monotony by their more rugged forms. They appear in castle-shaped rocks on the crests of andesitic mountains, and form high walls, naked and steep, along their slopes. Being more liable to destruction by the erosive action of water than solid andesite, they frequently compose the sides of steep ravines and cañons.

Mineral Composition.—Andesite is always of dark color, mostly blackish, though frequently reddish-brown on the weathered surface. Its mineral composition varies, though it is confined within more narrow limits than that of propylite. We may distinguish, in regard to it, two

Subdivisions. which are connected by gradual passage in composition and, in a greater measure, by geological relations.

Fam. 1. *Hornblendic Andesite.*—Paste of bluish-black to dark-gray color, and of microcrystalline texture, which passes by gradual steps into that of obsidian. In the former case it is frequently vesicular like trachyte. There are imbedded in it

small but distinct tabular crystals of oligoclase, fine grains of titanic iron, small, elongated columns of hornblende, sometimes mica, and in most varieties a few isolated crystals or rounded grains of augite. Frequently these different crystals are so small as to be no longer recognizable, except by the aid of the microscope. The rock is then similar in character to certain varieties of melaphyr, but may be distinguished by its vesicular texture, which is scarcely ever wanting in the hornblendic varieties. This family comprises vastly the greater portion of all andesitic rocks.

Fam. 2. *Augitic Andesite.*—Two groups of varieties may be distinguished among the rocks of this family. Those of the first have a paste of an oil-brown color passing into black, a compact appearance, and ordinarily a microcrystalline texture which passes into that of porcelain. Vesicular inflation does ordinarily not occur. Crystals of a monoclinohedric feldspar (probably labrador) are almost invariably enclosed, and frequently accompanied by hornblende and augite. For the rocks of this group the name "*trachydolerite*" has particularly been applied. The other group comprises certain varieties for which the name "*anamesite*" has not rarely been used, and which are of dark-gray colors. Their texture is in most cases vesicular. The enclosed minerals are the same as with the other group; but, while for this the feldspathic ingredient is more characteristic, and frequently alone present in large crystals, the rocks of the second group are distinguished by the predominance of well formed crystals of augite and hornblende, while those of feldspar are often so small that they cannot be distinguished by the eye. The rocks of both these groups contain titanic iron in larger quantity than those of the first family, and are of greater specific gravity. Olivine enters occasionally into their composition, in very subordinate quantity. Geologically, the rocks of this family are closely allied to hornblendic andesite. They have succeeded it in age, and are limited in their geographical distribution to those places where hornblendic varieties had been ejected before, frequently intersecting and overlying them. Notwithstanding the resemblance which they bear to certain varieties of basaltic rocks, they appear to be never associated with them geologically.

Order Fifth—Basalt.

No one of the names applied to volcanic rocks is of equal antiquity with that of "basalt," and with none there has ever been less change of opinion, and uncertainty in respect to its application. It may be inferred from this fact that the rocks comprised by that name are very distinct in character and little liable to variation, which is indeed true for the typical rocks of the order. But there have to be associated in the same order with them certain other rocks, which, though nearly related to basalt in regard to their chemical and mineral composition, differ from it in the more conspicuous external characters.

Mode of Geological Occurrence.—Basaltic rocks are more independent than those of any of the foregoing orders (perhaps with the exception of propylite), in respect to their epoch of ejection as well as to their geographical distribution. In the order of time they succeeded next to rhyolite, but locally, both are usually separated. Basalt occurs always in the neighborhood of more ancient volcanic rocks, but the cases

are rare when it intersects them and expands over them. Almost invariably it is found accompanying their ranges at some distance, forming itself extensive ranges; more frequently, however, it occurs in groups or lines of isolated outliers. It may sometimes appear to have no connection with the distribution of older volcanic rocks. But closer investigation will always show it to be within or in the neighborhood of the limits of former eruptive activity. The belts along which this had taken place may be locally interrupted for quite a distance, and the gap be filled by some isolated outbreaks of basalt, or the latter may extend the limits of those belts, in length as well as in width. It is a strange phenomenon that these isolated outbreaks of basalt occur particularly in connection with granite. It intersects this rock very frequently in small dykes, and expands over it in thin sheets. This connection of granite and basalt is very conspicuous on the eastern slope of the Sierra Nevada, and along the belt of basaltic eruptions which traverses the middle part of Germany. Such places are often the seat of basaltic volcanoes, which, though now mostly extinct, are also otherwise of very frequent occurrence.

Mineral Composition.—Basalt is the representative of what Bunsen has called the "normal pyroxenic type," and is thereby, as well as by its specific gravity, mineral composition, and little variety of texture, the reverse of rhyolite, which represents the "normal trachytic type." All the essential ingredients of basalt, and most of the minerals which enter accidentally into its composition, are different from those which are characteristic of rhyolite. Augite, labrador and titanic iron, imbedded in a paste consisting essentially of the same minerals, constitute generally the rocks of this order; or labrador may be replaced by leucite, nepheline or a zeolitic substance; or other minerals may enter into the composition, such as olivine, basaltic hornblende, hauyne, apatite and black mica; and in many instances basaltic rocks consist merely of a fine-grained aggregation of the different minerals mentioned. Ordinarily, the paste has a microcrystalline texture, and may either contain crystallized minerals imbedded, or may be devoid of them. This mode of texture passes by gradual steps into that of obsidian, which is the only hyaline variety occurring. Among the peculiarities of these rocks, and which may also in some measure be observed with augitic andesite, is the occurrence of rounded cavities filling the rock and giving it a cellular, sometimes spongy appearance. It is different in nature from pumice-stone, which is a modification of hyaline texture, while those cavities occur in microcrystalline rocks.

Subdivisions.—*Fam.* 1*st. Dolerite* (including nepheline-dolerite and the greater part of anamesite).—A crystalline aggregation of augite and labrador with titanic iron. Labrador is usually replaced by nepheline, either in part or totally. Accessory minerals are: olivine, hornblende, apatite, black mica.

Fam. 2*d. Basalt.*—Paste of dark-gray or black color, and of the varieties of texture mentioned; it constitutes either the mass of the rock by itself, or encloses olivine, augite and labrador, in crystals or crystalline grains. Besides these are frequently enclosed: titanic iron, black mica, rubellan, zircon, apatite and other minerals. This family comprises nearly the whole bulk of the rocks which constitute the basaltic order, the two other families being of rare occurrence.

Fam. 3d. Leucitophyre.—Rocks of porphyritic texture, crystals of augite and leucite being imbedded in the paste.

It will be noticed that no place has been assigned in this classification to phonolite. As regards those rocks for which this name was first proposed, our knowledge is still quite limited. It appears that, notwithstanding their comparatively rare occurrence, they form a distinct natural group closely allied to basalt; but they are so different from true basalt as regards lithological characters, that they should not be classified with it before further observations will have determined their real position in reference to the natural families of volcanic rocks. The name phonolite has, however, been so much extended in its application, that this task is not so easy to accomplish. Some external properties, easy of recognition to superficial observation, such as a certain tabular structure, lithoid texture of the paste, with small, bright crystals of feldspar enclosed, and the peculiarity of ringing by a blow of the hammer, which have been often considered as the characteristic features of phonolite, are just as common with certain varieties of trachyte and rhyolite, and even with some of propylite. It must be ascribed to this reason, that the name phonolite has been used for the designation of rocks which bear an accidental resemblance to true phonolite, but are distinct from it in nature. It has probably been oftener applied to rocks belonging to the trachytic order than to such as have the distinguishing features of those varieties for which the name has been first used.

Correlation of the Five Orders of Volcanic Rocks.

In the foregoing pages I have attempted to lay down the outlines of a classification of the volcanic rocks by natural principles, and to apply a nomenclature which should be appropriate to these, and embrace, at the same time, the most current of existing names. It is the next object of this paper to prove that these rocks are mutually connected by definite relations, and that their totality, in virtue of this property, forms actually what may be called a system in nature, and that the form into which we have tried to bring it, imperfect though it must be, is an approach towards its expression. In order, therefore, to fully realize the philosophy of the natural system, we have to contemplate the relations which, firstly, the rocks of the different orders offer mutually among themselves, and by which, secondly, they are connected as an entire class with ancient eruptive rocks; while we will have, thirdly, to examine into the mode of origin of volcanic, and of eruptive rocks in general, in order to establish the nature of their fundamental difference from sedimentary and metamorphic rocks. Our task is thus three-fold. The present chapter will be devoted to the first order of relations. They may be considered from several points of view, the more important of which are: chemical and mineral composition, geographical distribution, and all those complex relations which may be comprehended in the term "mode of geological occurrence." We will confine ourselves to the last point of view. But even with this restriction, we can only trace general outlines.

Laws relative to the Age of Massive Eruptions.

The succession of *massive* eruptions during the Tertiary and Post-tertiary ages has taken place in the following order:

1st. Propylite.
2d. Andesite.
3d. Trachyte.
4th. Rhyolite.
5th. Basalt.

This singular mode of succession, in which no regularity (as to increase or decrease of silica or specific gravity, or as to a gradual change of mineral composition) can be discovered at first sight, and which might indeed appear to be devoid of order, and to bear the character of such a succession as might have been occasioned by the coöperation of accidental circumstances in one single country, can nevertheless be proved to exist in widely separated parts of the globe. It may justly be objected to this assertion, that observations in regard to the relative age of different volcanic rocks are scarce, and hardly sufficient to establish definitely such a law. But hitherto no deviation from it has been discovered,[10] and it appears to be true for all volcanic regions on the globe, though with this restriction, that the epochs marked in each country by the ejection of rocks of any certain orders have not been contemporaneous in different countries. The commencement of eruptive activity in the Tertiary epoch has been earlier at one place than at another; it is its further mode of development in regard to the nature of the matter ejected which has everywhere been regulated by the same definite relations, though it has been independent, in some measure, at each place, or, to use a more correct expression, over the area of each belt of eruptive activity. We have to mention another restriction. Abrupt passage may be said to be an almost unknown conception in geological matters, where the order in time is concerned; nor has it to be applied to the order of succession of volcanic rocks. The eruptions of propylite appear not to have been interrupted by the ejection of any other rocks. This may too be said, though less strictly, of the andesitic epoch. But some, as it were, retarded eruptions of andesite, which, however, have always been insignificant, may occasionally be traced during the first part of the trachytic epoch, and similar relations exist between trachyte and rhyolite. Basalt, however, appears to have had everywhere its own epoch of ejection, uninterrupted by the massive eruptions of any other rock of the orders just mentioned.

We proceed to a short review of some salient facts observed in those countries where the mutual relations of volcanic rocks in regard to their age have been made an object of study.

In Hungary and Transylvania, propylite, as we have had occasion to mention, was ejected first of all volcanic rocks, and may be said to have inaugurated all sub-

[10] It must be borne in mind that we are speaking of massive eruptions. Apparent exceptions are known to occur with rocks ejected from volcanoes, of which mention will be made hereafter.

sequent eruptions of those belonging to other orders. At several places it has been observed to intersect Eocene strata, and to expand above them. The country of Nagybánya, Felsöbánya and Kapnik, the celebrated silver-bearing veins of which are enclosed in propylite, offers especially conspicuous illustrations; not less, from the descriptions given by G. Stache, the "Erzgebirge" of Transylvania, where the same kind of rock is rich in mineral veins. In this country, hornblendic propylite forms an older series, followed by eruptions of highly quartziferous varieties. In both countries, but chiefly in that first named, and at several other places along the southern slope of the Carpathians, andesite may be seen intersecting propylite in large massive dykes, and towering up above it in mountain ranges. Andesite composes entirely the Hargitta-range, which extends over one hundred miles in length, and twenty-five in width; the Vihorlat-Gutin-range, which is of still larger dimensions, and the Eperies-Kaschau-range; all of which are densely wooded, and of a gloomy, monotonous aspect. The only change observable on their summit ranges is a more or less dark color of the rock, occasioned by the predominance of augite or hornblende in its composition, (the augitic varieties being invariably of more recent age than the hornblendic), while their slopes, and particularly their ends, present a much greater variety in rocks as well as in scenery. It is here that the more silicious volcanic rocks are encountered. Trachyte is of rare occurrence; but it forms several isolated cones, some of which, on account of their prominent position, were crowned by castles in the middle ages. Rhyolite is much more frequently met with, bursting forth on the flanks, and skirting the foot of the andesitic ranges, particularly where they verge towards the Hungarian plains, which in the rhyolitic epoch were still covered by a shallow and slowly retiring sea. It projects against this in promontories, which are now covered by the most celebrated of the Hungarian vineyards, those of Tokay among others. The boundaries of these vineyards towards the adjoining beech forests mark the dividing line between rhyolite and andesite. An interesting mode of occurrence of the former may be witnessed in large circular or amphitheatrical basins which are surrounded by andesite. Such places are the theater, especially, of the volcanic activity connected with the outbreak of rhyolite, and abound in endless hyaline varieties of the same. Telkibanya is the most interesting among the localities of this description. There is no lack of evidence to prove that trachyte and rhyolite are both of more recent age than andesite, while the assertion that trachyte preceded rhyolite in age, rests only on a few though conclusive observations. Basalt occupies a singular position in the geology of Hungary. It keeps altogether aloof from the places occupied by the other four orders of volcanic rocks, and forms extensive, though isolated, hills at some distance from them, scattered over a wide range of country. It would be difficult to determine its relative age, but for the volcanic sediments which were of formation contemporaneous with the ejection of the different volcanic rocks, and have been spread over wide areas at the bottom of the then existing sea, with fossils occasionally imbedded. In several localities, especially in the neighborhood of Kaschau, basaltic sediments may be seen, covering those composed of rhyolitic matter, while at Gleichenberg in Styria, Mr. Franz von Hauer has observed fragments of rhyolite enclosed in basalt.

The observation of these relations in Hungary and Transylvania has first given

rise to the establishment of the above mentioned law of the periodical succession of volcanic rocks. [11] It has since been corroborated by observations made in other countries far remote from the Carpathians. Near Nangasaki, in Japan, andesite preceded trachyte in age, and of the former there are two varieties represented, one augitic and one hornblendic, of which the former is of more recent origin than the latter: thus, even the more minute relations observed in the Carpathians are repeated in other countries. The islands of Java and Luzon are too intensely volcanic and covered with lava to aid in establishing the laws in respect to massive eruptions without very close observation. But another region offering copious evidence is that of the Sierra Nevada, together with the adjoining parts of the Great Basin. Observations in these countries are still limited as regards our present subject. The great part, however, which volcanic rocks take in their composition, as well as in that of the highlands of Mexico, and of the entire range of the Andes, promises to make the Western Coast of America the most prolific source of observations necessary for the definite establishment of geological laws of which, at the present day, we can only trace the first foundation.

In Washoe, a country adjoining the Sierra Nevada immediately to the east, propylite forms extensively the foundation for all other volcanic rocks, which fact proves clearly its priority in age. It composes the plateau of Virginia City and Gold Hill, and derives a practical interest from the fact that the Comstock vein is enclosed between propylite and syenite, though in some parts of it both walls consist of the former rock. Andesite is insignificant in bulk in that region. It composes a few small hillocks on the propylitic plateau, and in some cuts and tunnels andesitic dykes may be seen, which appear to have been the feeding channels of the surface accumulations. Trachyte, on the contrary, is among the prominent rocks of Washoe. It forms a high and rugged crest, encircling the plateau of Virginia and Gold Hill to the east, and extending for miles to the north, while to the south it reappears across the Carson River. No evidence is afforded, in Washoe, for the establishment of the mutual relations of andesite and trachyte, while it is conspicuous that the latter was of later origin than propylite. Besides the evidence offered by intersection and superposition, another fact may be noticed which is suggestive for the length of the period that elapsed between the eruptions of both rocks. It is this, that propylitic sediments occur, at least, at one thousand feet more elevation than those consisting of trachytic matter, which fact appears to indicate that the former have been deposited at a much earlier part of the period marked by the gradual subsidence of the inland seas of the Great Basin than has been the case with trachytic sediments.

At Silver Mountain, propylite, of the augitic variety, fills the bottom of a deep basin encircled to the west by granitic walls several thousand feet in height. Its massive accumulations are intersected by andesitic and trachytic rocks, which latter appear to compose the summit of the high peak of Silver Mountain itself, while rhyolite occurs in such a position as to make it probable that it has arrived at the surface last of all eruptive rocks. Basalt appears to occur only to a limited extent at Silver

[11] Richthofen, loc. cit.

Mountain. But this rock is largely distributed in the regions adjoining the Sierra Nevada to the east, and bears evidence of its recent origin. It is the only volcanic rock which covers in places the sand of the deserts, and the belts distinguished by its eruptions are still marked by the occurrence of hot springs and other post-volcanic phenomena. Most of these are contiguous to those places where basalt and granite are in close contact, as is very conspicuously the case at Steamboat Springs, near Washoe, and in the Coso Mountains. No phenomena of similar nature appear to be connected at the present time with any other volcanic rock east of the Sierra Nevada. There are not a few instances where basalt may be seen covering propylite or andesite; but I met with only one case where it comes in contact with rhyolite, close enough to establish their mutual relations. This is in Esmeralda, on the eastern slope of the Sierra Nevada, a country of unusual interest for the study of volcanic rocks in general. Propylite encloses the silver-bearing veins of that place. It is overlain by trachyte and rhyolite, both of which occur in very great variety. To the east of the place, basalt has not only flowed over rhyolite, but contains numerous fragments of it enclosed, which fact confirms also for this country the more recent origin of basalt.

Many other examples might be added to this short list, partly of positive observations made in the countries already mentioned, and partly of facts described in treatises on the geology of other countries, such as Armenia, the Caucasus, Central France, the Eifel, Bolivia, Mexico. As these descriptions, however, have not directly in view the illustration of our subject, great care should be used in drawing from them conclusions in regard to it. Let it suffice to remark, that every observation on record which bears on our subject, appears to confirm the proposed law, while none can be found giving evidence against it. This may justify the assumption that the periodical succession of volcanic rocks, in the order above mentioned, is a general law, true for all parts of our planet.

Laws regarding the Mutual Relations of Massive Eruptions and Volcanic Activity.

It has been mentioned in this chapter, that the law of the periodical succession of volcanic rocks regards those outpourings of large volumes of matter not resulting from volcanic activity proper, and which we called massive eruptions. For convenience' sake, we make use of the following expressions: *propylitic epoch; andesitic epoch; trachytic epoch; rhyolitic epoch; basaltic epoch* — designating thereby those epochs in which the *massive* eruptions of rocks belonging to each of these orders, have taken place in every different country. If we now direct our attention to the other mode of manifestation of subterranean energy, the *volcanic* eruptions, a cursory review of active volcanoes in regard to the nature of the rocks which they eject, shows that the same law is no longer true for them, as their lavas belong to several different orders of volcanic rocks. It is, however, known that each volcano ejects lava or scoria belonging petrographically only to one distinct order, and the examination of the material accumulated by former activity will show that with most volcanoes the nature of the rocks ejected has never materially varied, while with some of the

grander vents it has undergone a periodical change. Volcanoes, whether active or extinct, may be classified from this point of view. We shall distinguish: *andesitic, trachytic, rhyolitic* and *basaltic volcanoes*, according to the nature of the mineral matter which each volcano has ejected *in the first epoch* of its activity, regardless of any later changes. Two noteworthy relations may be traced between these different orders of volcanoes and the massive eruptions of the synonymous orders of volcanic rocks. The first of them is the alliance of both in regard to geographical distribution, the volcanoes of each order being limited, in this respect, to the immediate neighborhood of massive accumulations of rocks similar in nature to their first lavas. From this may partly be inferred the second relation, that the massive eruptions of each order have been succeeded by volcanic activity, which occasioned the ejection of lava corresponding in nature to their own rocks, and continued for long after-time, in many instances to the present day. This dependence of volcanoes upon massive eruptions explains why the number of active volcanoes is so small when compared with those which are extinct, and why the present activity even of those which are still in operation, appears to be only a faint remnant of that which the same vents exhibited in former time. It will further explain why no vestige can be found of a rhyolitic volcano having been active before the rhyolitic epoch, or of a basaltic volcano having originated before the basaltic epoch, while geological observation goes to show that during, and immediately after those epochs, the volcanoes of either order have been most intense, numerous and extensive, and their activity has, from that epoch of culmination, gradually relaxed, in most cases to perfect extinction.

An instructive instance of one of those grander volcanoes which have undergone a periodical change in regard to the nature of the matter ejected from them, is afforded by the extinct volcano Lassen's Peak, in Northern California, which Professor J. D. Whitney and I visited in 1866. We found it to have been originally an andesitic volcano, and it has to be ranked as such in our proposed classification. The enormous bulk of the ancient volcano is totally built up of stratified layers of andesitic tufa and rapilli, which, in the steep gorge issuing from its lower crater, are exposed in a thickness of nearly four thousand feet, notwithstanding the total destruction which the upper part of the former cone has undergone, and the fact of its lower parts extending down far beneath the present surface, and being therefore concealed to view. Besides these stupendous accumulations of loose matter, currents of andesitic lava appear to have been emitted from the crater, extending at least twenty miles from the place of ejection. At a later epoch, the activity of the same volcano has been distinguished by the emission of trachytic lava from the northeastern part of the wall of the crater; its currents have expanded to elongated and sloping tables, bounded by abrupt descents. A third epoch is marked by the outbreak of rhyolite at the same place whence the trachytic rocks had issued. Rhyolite composes the present summit of Lassen's Peak, on which it is accumulated in a thickness of more than fifteen hundred feet, also some other summits of less altitude, and at least one prominent current of lava of great volume.[12] The noteworthy fact illustrated by these observations on Lassen's Peak, and corroborated in numerous other instances, is this:

[12] Mr. Clarence King has observed the occurrence of basalt of apparently very recent origin immediately north of

that the same law of periodical succession which has been established in regard to massive eruptions, is true for volcanic action, particularly when this happened to assume such unusual intensity and dimensions, and has been of as long duration as was the case at that volcano.[13]

Summing up these considerations on the correlation of the different orders of volcanic rocks in respect to the age of their emission through volcanic vents, we arrive at the following conclusion: The commencement of the activity of the volcanoes of each separate order has been nearly coincident with, though in every instance successive to, the main phase of the corresponding massive eruptions. Thence it has, by each separate vent, either continued emitting similar material to that first ejected, until its extinction, or it continued in the same way to the present day, or it has been subjected to a periodical change in regard to the nature of its lavas, and this change is analogous to that exhibited by the succession of massive eruptions. In this case, as in the former, the volcano has either become extinct when in a certain phase, or it is still active. We are thus furnished with a natural cause of the fact, that most active volcanoes are emitting basaltic, a smaller number of them rhyolitic or trachytic rocks, while andesitic lava is peculiar only to a few of them, especially to some of the prominent volcanoes of South America (Chimborazo, Cotopaxi, Antisana, Tungurahua, also Popocatepetl, Colima, and Teneriffe) which appear never to have changed in mineral character. It will, too, be self-evident, why generally no material change in the nature of their lava should have been observed in regard to those volcanoes which have originally emitted basalt and constitute our order of basaltic volcanoes.

A few more instances may here be mentioned in support of our propositions. The interest attaching to volcanoes has furnished us with a much greater number of facts in regard to volcanic rocks when occurring as lavas, than we possess in regard to the grander and more frequent instances when similar rocks have been produced by the comparatively neglected action of massive eruptions. Among those observations, none will be better evidence than such as prove the abrupt succession, by ejection from the same volcano, of two rocks so dissimilar in composition as rhyolite and basalt. On the other hand, the nature of volcanic action will explain why we should meet among lavas, more frequently than among massive eruptions, with the fact of two successive epochs blending into each other by the alternation of the two kinds of rock peculiar to them separately, and it cannot be surprising if instances are occasionally observed exhibiting, at least partly, a reversed order of succession.

Lassen's Peak. It is probable that it indicates the existence of a fourth epoch in the activity of that volcano. The ejection of basalt has been so frequently connected with the opening of vents in the neighborhood of, but not coinciding with, channels through which its predecessors had ascended, that its local separation cannot be an argument against its belonging, in our case, to the system of Lassen's Peak.

[13] The fact that trachytic lavas are frequently followed by such of basaltic character has been known since long time, and was till now the only law of succession observed. Mr. Scrope has suggested the hypothesis indorsed by Mr. Darwin, Sir Charles Lyell, and other distinguished geologists, that in the subterranean reservoirs of volcanic matter, the heavier particles will occupy the lower part, and the lighter ones be nearer the earth's crust. It will easily be seen how totally inadmissible this theory is in the case of Lassen's Peak. It is not less so in those cases where rhyolite was succeeded by basalt, since the process of liquation can certainly not be supposed to have produced an abrupt passage under ground from one mass to the other, and it would be much more natural to suppose a gradual transition to take place, there as well as in the succession of the rocks emitted to the surface, if liquation had really taken place.

An instance, which is instructive on account of its simplicity, is furnished by the island of St. Paul, in the Indian Ocean. F. von Hochstetter found its foundation to consist of rhyolitic rocks. These are intersected by basaltic dykes. Rhyolite overlays the first basaltic formation, and is itself superposed, first by dolerite and then again by basalt. These two rocks of the basaltic order constitute the main body of the island, and encircle its crater. Similar relations, though on a much grander scale, have been observed by the same eminent geologist on New Zealand. More frequently than this order of succession between rhyolitic and basaltic lava, has been observed the sequence of basalt to trachyte, with the omission of rhyolite, or immediately to andesite, when both those rocks are absent. Vesuvius is built up of rocks of the basaltic order, and still emits lava corresponding in mineral character to its predecessors, while the rocks of its surroundings (Campi Phlegræi), on the prior origin of which geologists agree, are trachytic. The industrious explorer of Mount Etna, Sartorius von Waltershausen, has described its foundation as being composed of white and reddish colored trachytic rocks, which contain hornblende as a characteristic ingredient, while among those rocks which build up the summit, as also in all modern lava of the volcano, no hornblende but, in its place, augite is visible. This mineral and labrador compose the recent lava, which belongs to the basaltic order. The much more extensive recurrence of a similar order of succession in the Eifel and in Auvergne, is too well known from the accurate descriptions of the geology of those regions, to require to be here more fully mentioned. It contributes especially to confirm our proposition, that the volcanoes of the different orders, as regards their origin, have been nearly contemporaneous with the correlated massive eruptions. The classical descriptions of the Eifel, by Mr. von Dechen, give conclusive evidence thereof.

Among those volcanoes the lava of which has never undergone a material change and is, at the same time, similar in nature over the area of larger volcanic districts, may be mentioned, besides numerous basaltic volcanoes, those of the trachytic order in Central, and those of the andesitic order in South America, as far as may be seen from the descriptions given of them.

We might greatly enlarge this enumeration of observations confirming our propositions; but, as by most authors only a "trachytic" or a "basaltic" character of lava have been mentioned in a general way, they would only furnish evidence in favor of the general tenor of the law, but would fail to give it in regard to any of its details.

Relation of Volcanic Rocks to Ancient Eruptive Rocks.

All rocks which, bearing evidence of an intrusive or eruptive origin, preceded in age the Tertiary period, may, by principles similar to those which we applied in tracing the natural system of volcanic rocks, be divided into two great classes, for which we may use the terms "granitic rocks" and "porphyritic rocks," derived from the mode of texture predominating in either class. Granitic rocks are, besides, geologically associated with granite, which is their principal type, while quartzose porphyry occupies a similar position among porphyritic rocks. The annexed table

First Class: Granitic Rocks.	Second Class: Porphyritic Rocks.	Third Class: Volcanic Rocks.		Essential Ingredients.
Order First—Granite.	*Order First—Felsitic Porphyry.*	*Order First—Rhyolite.*		
Fam. 1st. Granite.	Fam. 1st. Quartzose Porphyry.	(Quartziferous Varieties.)	Fam. 1st. Nevadite.	Quartz, Orthoclase, Oligoclase, Biotite, (Hornblende.)
Fam. 2d. Granitite.	Fam. 2d. Varieties without Quartz.	(Varieties without Quartz.)	Fam. 2d. Liparite.	
Fam. 3d. Syenitic Granite.			Fam. 3d. Rhyolite proper.	
Order Second—Syenite.	*Order Second—Porphyrite.*	*Order Second—Trachyte.*	*Order Third—Propylite.*	Oligoclase, Orthoclase, Hornblende, (Biotite), (Quartz.)
Only Family: Syenite.	Only Family: Porphyrite.	Fam. 1st. Sanidin Trachyte.	Fam. 1st. Quartzose-Propylite.	
		Fam. 2d. Oligoclase-Trachyte.		Oligoclase, Hornblende, (Titaniferous Magnetic Iron ore.)
Order Third—Diorite.	*Order Third—Melaphyr.*	*Order Fourth—Andesite.*	Fam. 2d. Hornblendic Propylite.	Oligoclase, Hornblende, Titaniferous Magnetic Iron ore.
Fam. 1st. Diorite.	Fam. 1st. Melaphyr.	Fam. 1st. Hornblendic Andesite.		
Fam. 2d. Rocks intermediate between Diorite and Diabase.	Fam. 2d. Rocks intermediate between Melaphyr and Augitic Porphyry.	Fam. 2d. Augitic Andesite.	Fam. 3d. Augitic Propylite.	Oligoclase, Labrador, Augite, Hornblende, Titaniferous Magnetic Iron ore.
Order Fourth—Diabase.	*Order Fourth—Augitic Porphyry.*	*Order Fifth—Basalt.*		Labrador, Augite, Titaniferous Magnetic Iron ore.
Fam. 1st. Gabbro and Hypersthenite.	Only Family: Augitic Porphyry.	Fam. 1st. Dolerite.		
Fam. 2d. Diabase.		Fam. 2d. Basalt.		

will show the mutual relation of these two classes and their subdivisions, and of either of them to volcanic rocks.[14]

It appears that this general classification is based upon as natural principles as are within reach of our still limited knowledge of eruptive rocks, and therefore may at least approach the natural system. The following are the systematical principles chiefly involved :

1st. *Chemical Composition.*—Each class contains all possible compounds intermediate between those which Bunsen styled the normal trachytic and normal pyroxenic types, and may, therefore, be represented by a numerical series of infinite gradations within two certain limits, and progressing according to a definite arithmetical law. If this law applied to the composition of rocks with mathematical precision, it would be sufficient to know the relative quantity in which any one single ingredient enters into the same, in order to find by calculation the relative proportion in which every other ingredient should be present. It is, however, well known, that analysis shows ordinarily a slight deviation from the composition as required by theory ; and, considering the various influences to which the rocky masses must have been exposed before and after their consolidation, we should naturally presuppose that such deviations would be the rule, and may indeed be astonished to see how slight they generally are. Silica has been found to be not only the most convenient, but also, on account of its predominance over other ingredients, the safest element by which to determine the place any rock occupies in the series. In the classification as proposed in the preceding page, each class of eruptive rocks commences with those varieties of granite, quartzose porphyry and rhyolite, which contain the highest amount of silica as found by analysis, and descends to the most basic varieties of diabase, augitic porphyry and basalt. In a chemical respect, therefore, the three classes are identical.[15]

[14] This table is only designed to show the mutual relations of the subdivisions of the three great classes of eruptive rocks in their most general outlines. I have purposely avoided to detail them any more, since it appears that great progress in regard to their knowledge will be made in the next years, and considerable changes in the details of classification may have to be looked for. The composition of eruptive rocks is just at the present time being made an object of more careful study than it ever was before. Contributions of high value in regard to the chemical and mineral composition of volcanic rocks are being furnished by the members of the Geological Institute of Vienna; while H. Abich continues with untiring energy his fruitful researches on the same rocks of Armenia, the Caucasus, and the borders of the Caspian Sea. The examination of the granitic rocks by G. vom Rath, A. Streng, Th. Scheerer and many others; the more general labors of G. Rose, Robert Bunsen, A. Delesse, G. Bishoff, F. Zirkel; the microscopic investigations which have been commenced with so much success by A. Sorby, and are being extended by his numerous followers—all these labors pursued zealously by those named and a great many other workers in the same branch of geological science, whom it would be too lengthy to mention, promise a rapid advance of our knowledge of the properties of eruptive rocks. In respect to their mineral composition, the discovery of some new species of feldspar (such as the plagioclase of Rath and the microtine of G. Tschermak) which appear to be of wide distribution among the components of eruptive rocks, promises alone to enlarge quite considerably the basis of classification, as it appears to give a clue to the causes of the differences in outward appearance (frequently referred to in this paper) of rocks which are alike in regard to their chemical composition, and among the mineral ingredients of which no difference could be recognized heretofore.

[15] Objections have been raised against the validity of the law of Bunsen, partly on the ground of the frequent discrepancy of the figures obtained by chemical analysis from those which would be required by the theory, and partly on account of the highest and lowest amounts of silica occurring in eruptive rocks having as yet by no means been fully ascertained. We referred above to the first objection. As regards the second, it is evidently very trifling in importance. The limits of the series may, and probably will, be somewhat extended, and the figures representing the compounds which form those limits may have to be slightly changed, yet the series itself will remain essentially the same. The law of Bunsen will have to be revised and corrected when increased experience shall have established a broader basis for it ; but no change of its principles may ever be expected, as an overwhelming amount of evidence has accumulated in support of its essential tenor.

2d. *Mineral composition*, in respect to which each class represents a series of gradations essentially dependent on the chemical composition, and therefore chiefly coincident with the chemical series, but differing from it inasmuch as it is more articulate. Certain types, corresponding to certain steps in the chemical scale, and consisting in distinct aggregations of a few minerals, are the centers for which the petrographical names have been applied in the first place ; around them other members are grouped which connect every two types by gradual passages, and are ordinarily composed of an aggregation of all the minerals peculiar to either of them. Expansion of the series, as it were, in a lateral sense, occasioned by the accession of minerals inferior in importance, are not unfrequent, but do not affect in a great measure the definite character of mineralogical gradation, as they are of local occurrence, and probably less dependent upon any material differences in chemical composition, than upon certain influences which acted upon the mass of the rock, either before its ejection, and then by the admixture of matter differing from it in nature, or after its solidification, and then by chemical metamorphism.

3d. *Specific gravity*, which increases in the reverse proportion of silica. In this respect, too, each class represents a series of infinite gradations from the lowest to the highest value.

Taking the three foregoing principles exclusively as the basis for classification, all eruptive rocks would have to be united into one class. This union, made regardless of any other relations, may be traced as the leading feature of nearly all systematical arrangements proposed. There are, however, other points of view which must be considered if a more perfect classification is aspired. They lead to the establishment of further separations, by principles similar to those which we had to apply above in defining the different orders of the compounds of hornblende and oligoclase among volcanic rocks. These points of view are the following :

4th. *Mode of Texture.*—Eruptive rocks exhibit, in regard to their modes of texture, very peculiar differences, which are little capable of explanation with our present state of knowledge. They are especially conspicuous with the most silicious rocks. Free silica, in granite, has probably been solidified cotemporaneously with the other component minerals ; but its solidification appears often to have been completed last of all, as the quartz does envelop the aggregation of the other crystals. In quartzose porphyry and rhyolite, on the other hand, free silica, at least the greater part of it, has been solidified first, which is obvious from the fact that its perfect crystals are imbedded in an ordinarily microcrystalline aggregation of the other ingredients, which however contains, in most cases, some surplus of free silica that had not entered into the composition of the crystals. This fundamental difference from granite points to some difference in the mode of origin. Quartzose porphyry and rhyolite differ in regard to the texture of their paste, which has a compact aspect in the first, while it is more or less vesicular throughout the mass in most varieties of the latter. This difference, like the former, appears to indicate, that the molecular condition of the liquid mass, at the time when it was ejected, was different in either case. The variety of texture diminishes with the decrease of silica, and the more basic rocks of the three classes bear a much

closer resemblance to each other than the silicious rocks. The cause must be, either that the conditions of the mass before cooling were less varied with basic than with silicious rocks, or that the differences were alike, but manifested themselves less conspicuously in the character of the solidified rocks; the latter cause is the most probable of the two, since even our cotemporaneous basaltic and andesitic lavas offer but a small number of varieties comparing with those of rhyolite or trachyte, although it is not likely that there is any more variety among the circumstances modifying the latter than among those which are acting upon the former. It is chiefly the similarity in texture which has occasioned the general application of such names as "trap," "greenstone," "aphanite," and others, for basic rocks of all ages, while those containing a large amount of silica have scarcely ever been similarly confounded. We may, however, note this difference among the former, that granitic texture—that is, a crystalline aggregation of the component minerals—is peculiar to those basic rocks associated with granite, while the vesicular or trachytic texture is only proper to volcanic rocks. Occasionally, though very rarely, rocks of granitic texture are geologically associated with porphyritic rocks, as is the case near Predazzo, in southern Tyrol.

5th. *Geological age;* granitic rocks being generally the most ancient in origin, volcanic rocks the most recent, while those of porphyritic structure are intermediate in age between both.

6th. Other geological conditions resulting from the correlation of the different foregoing principles, the outlines of which I will attempt to trace in the following pages.

Correlation of Age and Texture.

It is scarcely possible to treat of one of the foregoing principles in its application to eruptive rocks singly, without constantly encountering points of intimate connection with others, so thoroughly are they intertwined and mutually dependent. It is the object of petrology to develop these correlations. We contemplate them here only in their purely geological bearings, in order to try to establish the true relation of volcanic rocks to their ancient predecessors. We have, while occupied with these considerations, constantly to keep in view how few are the observations upon the strength of which we have to base conclusions. The area on the globe whose special geology has been made the object of investigation, though extending every year, is still very limited; and even in the best explored countries, little attention has, in most instances, been paid to the distinction of eruptive rocks. Observations in regard to them are abundant in some parts of Europe, fortunately in such countries as are especially capable of giving a clue to their general knowledge. Distinct conclusions may be arrived at in regard to portions of that continent, but little scope is afforded for giving them latitude by comparison with the relations presented in other countries. We have, therefore, to keep well separate in general petrology, those positive conclusions which are founded upon sufficient observations, and are applicable to the relations in those countries where the latter were made, and the realm of theories, which are arrived at, partly by the generalization of those conclusions, and partly by making deductions from hypothetical suppositions; because, the premises being founded

on local occurrences, and their general validity not being proved, the theories must necessarily have a great deal of uncertainty, which will only gradually be dispelled by the advancing knowledge of the geology of the globe.

The correlation of age and texture, as resulting from observations made in Europe, will occupy us first. Granitic rocks are widely distributed on that continent. Their great eruptive masses are of Azoic and Palæozoic age. The rocks have almost throughout granitic texture, though the distinguishing features of porphyritic rocks are proper to some subordinate varieties of diorite and diabase. The eruptive activity exhibited in the granitic era gradually relaxed. It appears to have been insignificant, though it was by no means extinct, in the latter part of the Devonian and the first part of the Carboniferous periods. But it recommenced about the time of the deposition of the coal measures, thence increased in intensity, and was most violent in the Permian age, though it was, during all that time, much more limited in extent than it had been during the granitic era. The middle portions of Germany were then its principal theater, until it changed, in the commencement of the Triassic age, to the southern slope of the Alps and Carpathians. The rocks produced during this era possess, almost exclusively, porphyritic texture. The Jurassic, Cretaceous, and the first part of the Tertiary ages, were distinguished by an almost complete repose of eruptive action, in Europe. It was only after the commencement of the Tertiary period when that violent resumption of eruptive activity took place to which we have repeatedly called attention in the foregoing pages, and which thereafter continued, gradually relaxing, down to our present era, the manifestations of volcanic action in which are its last faint remnant. Vesicular inflation, which is the characteristic feature of trachytic texture, is peculiar to the rocks of this class; all of them possess it more or less, though there are varieties resembling porphyritic rocks closely in aspect. A combination of the trachytic and porphyritic modes of texture is of more common occurrence than either of them singly, and is indeed the distinguishing feature of volcanic rocks.

These relations of age and texture have been conclusively proved to exist in Europe, and appeared to justify the conclusion, that the three classes of eruptive rocks are geologically separated, and represent three successive and distinct phases of the manifestation of subterranean agencies. Considering in their generality the facts observed in other countries, they appeared to confirm these views, since granitic rocks are known to be generally very ancient; volcanic rocks to have been generated during the Tertiary and Post-tertiary periods; while, in regard to porphyritic rocks, observations have been scarce, and descriptions lack distinctness, yet no relations have been recorded in reference to them which would be contradictory to those observed in Europe. On the western coast of North America, however, eruptive rocks exhibit some peculiar relations—differing to some extent from those which they offer in Europe. Positive facts are known sparsely outside of California, but conditions similar to those observed in that country appear to be repeated through large portions of the range of the Andes. Prof. J. D. Whitney's admirable researches on the age of the metamorphic rocks of the Sierra Nevada have clearly demonstrated that the granitic rocks, which partake to

great extent in the structure of that mountain range, cannot possibly have been ejected prior to the Jurassic epoch. The texture of these rocks is, notwithstanding this comparatively recent origin, that of all true granite, and the prominent varieties cannot be distinguished from some European kinds of granite, as for instance those of the Adamello and the Cima d'Asta in the Southern Alps, which are among the most recent in age on that continent. Volcanic rocks are widely distributed in the Sierra Nevada, and are of the same or similar age as in Europe. Quartzose porphyry occurs to some extent in Washoe, under circumstances which make the exact determination of its age difficult, but render it certain that it is intermediate in this respect between granitic and volcanic rocks. These relations would appear to be an exact counterpart of those observed in Europe, with the one prominent difference, that the commencement of the eruptive action was much later in America. Very recently, however, additional observations have been made, which give a somewhat different aspect to these relations. Mr. Clarence King observed granite, covered by Palæozoic rocks and antecedent to them in age, near the Colorado River; while Prof. Whitney and myself discovered true quartzose porphyry in the county of Plumas, in northern California, associated with rocks proved by the former to be of Triassic and Liassic age, in such way as to leave little doubt about its cotemporaneous origin. Farther east, in the Great Basin, Palæozoic granite is of no rare occurrence, and it is among the prominent features in the geology of the Rocky Mountains; while the discovery of porphyritic rocks may have to await further examination, they having been in most countries the last eruptive rocks to be detected.

However these facts may affect the theoretical conclusions in regard to the origin and mutual relations of granitic and porphyritic rocks, which had been made on the strength of former observations, they appear to confirm the separation, from a geological point of view, of both classes of rocks. There has been in the Sierra Nevada and adjacent countries, it appears, an ancient granitic era corresponding to that of Europe, followed by a porphyritic era which was nearly or quite coincident with the European. But, while the manifestations of subterranean agencies almost ceased in Europe during the following ages, they recommenced with great intensity on the western coast of North America, and gave rise to a second granitic, followed by a second porphyritic era. The volcanic era commenced in both countries in the Tertiary epoch, but it appears to have been in an advanced stage in Europe while it was still in its birth-throes in America.

Correlation of Age and Composition.

This point of view is not inferior in interest to the foregoing. The most noteworthy fact is this, that quartzose, and in general highly silicious rocks prevail among those of ancient origin, basic compounds among those of later ages. Granite and syenite are overwhelmingly predominant among ancient eruptive rocks. Diorite and diabase are generally associated with them, but remain always quite subordinate in bulk. The relative proportion is different with porphyritic rocks. So little attention has been paid to these, outside of Europe, that general conclusions in

regard to them should be drawn with care. In the middle part of Germany, and in southern Tyrol, where they have been repeatedly studied, subjected to chemical analysis, and described in numberless treatises, quartzose porphyry is rather predominant. But porphyrite, melaphyr, and augitic porphyry, are, in the aggregate, little subordinate in bulk. The volcanic offers the complete reverse of the granitic era, respecting the proportionate quantity in which the different compounds have come to the surface. Andesite and basalt compose as large a proportion of the aggregate bulk of volcanic rocks, as granite and syenite do of those of the granitic era.

Some minor differences in age may be noticed among the different orders composing the three classes of eruptive rocks. Extrusions of granite and syenite appear to have been almost the exclusive feature of the eruptive activity during granitic eras, and to have been succeeded only towards their close by the emission of diorite and diabase, or of other rocks of limited occurrence, such as gabbro and hypersthenite. Such at least has been observed to be the case in several countries, in regard to the chief outbreaks; but if we enter into the details of the mode of succession of the rocks belonging to the different orders, we perceive that it has not been so definite as with volcanic rocks—granite and syenite bearing evidence, in many localities, of a more recent age than some neighboring masses of basic rocks. Yet, in keeping only the main features in view, we may easily see, that the general order of succession of granitic rocks has been conformable to a gradual decrease in silica. Syenite is usually more recent in origin than granite; and even among the different varieties of the latter, true granite, containing the highest ratio of silica, has generally been anterior in age to G. Rose's granitite. There may be some connection between these relations as they are exhibited in any single granitic district, and the fact that the granitic rocks of the Sierra Nevada, belonging altogether to a more recent era, contain no true granite—their chief bulk consisting of rocks intermediate in composition between granitite and syenite. The porphyritic era, in Germany and on the southern slope of the Alps, was inaugurated by eruptions of quartzose porphyry, and has terminated in the Alps by those of augitic porphyry. The intermediate epoch has been distinguished by rocks intermediate in composition. The mode of succession of the different orders is more distinct than with granitic, but less so than with volcanic rocks. Melaphyr and porphyrite interchange frequently; but, at many places, the former appears to have preceded the latter in age, in a similar way as andesite preceded trachyte. They form together one epoch, which, in the commencement, was occasionally interrupted by an outbreak of quartzose porphyry.—The laws of the periodical succession of the five orders of volcanic rocks have been developed in the foregoing pages. Their epochs are much more distinctly separated than those of the ancient rocks, but the mode of their succession is more complicated. With granitic rocks, silica as a component part decreases with the age; with porphyritic rocks the same is true in a broad sense—the precedence in age of melaphyr and porphyrite forming the only conspicuous deviation; while in reference to the volcanic era, no rule at all may be discovered at first sight. Considering, however, the predominant rocks of that era, which are propylite,

andesite, and basalt, we perceive that the former two were the precursors of the latter, containing at the same time silica in a proportion superior to basalt. The singular phenomenon of trachyte and rhyolite being ejected at a time intermediate between the epochs of those rocks, is a notable deviation from the mode of succession peculiar to granitic and porphyritic rocks. We will try to consider its probable causes in another chapter.

Correlation of Eruptive Rocks in regard to their Geographical Distribution.

Another point of view offering in the contemplation of eruptive rocks, and which has a close bearing to their natural system, is the correlation among them in regard to their geographical distribution. This is, however, a vast subject, and volumes might be written in collecting evidence for final argument of general value. At this place we can give it only a cursory notice. We will consider, first, what is the mode of distribution peculiar to each class of rocks, and then trace the correlations perceptible among them in regard to their different modes of distribution.

Granitic rocks are scattered widely over the globe. Wherever its surface is composed of ancient sedimentary rocks, and these give evidence of disturbances of some intensity, by the plication of their strata, we may be almost certain to find granite entering into the geological composition to some extent. In the diversified structure of the European continent, geological maps show the existence of granite in nearly every prominent mountain-range. Considering among them the range of the Alps and Carpathians, we find granite scattered over its whole extent, from Savoy to Transylvania, particularly on the southern slope. It forms some prominent summits, but occurs also in subordinate positions. The geological relations of several of these places have been examined, and careful investigations made of the mineral and chemical composition of the rocks. They have resulted in proving an individuality of granite such as is peculiar to no other kind of eruptive rocks; different granitic masses are of different age, and exhibit a corresponding diversity in regard to the composition of the predominating rocks. Sometimes, it is true, several neighboring masses are similar in respect to their petrographical character, and bear evidence of being nearly of the same age (for instance those of the Adamello, the Cima d' Asta, and Brixen), but others, next adjoining, will be found differing from them in nature and in age. The length of geological time during which they have been ejected, has never been established; but the period appears to have been one of immense duration. A similar individuality as to age and mineral character may be noticed in respect to the granite of other mountain ranges on the European continent. Altogether, the mode of distribution of the ancient granitic rocks, as far as they enter into the structure of the surface, may be said to be in numerous small districts, which are independent of each other in regard to their epoch of ejection and petrographical character. With reference to the latter, each separate district shows a great preponderance of rocks belonging to one of the families of the granitic order, which are usually accompanied by syenite in smaller proportion, and by some subordinate eruptions of diorite and diabase. These districts are principally scattered along the present lines of eleva-

tion. But this may be due in part to their concealment, in the spaces between those lines, by sedimentary rocks. More signs of the separation of distinct "regions of eruptive action," as they may be called, are exhibited in the porphyritic era. Eruptive activity has been intense within them, but appears not to have spread beyond certain boundaries. Each of these regions embraces a number of the former granitic districts, while it leaves others excluded. Some resemblance with the peculiar features of the granitic era is afforded, inasmuch as each porphyritic region has been independent from others in regard to the epoch of its eruptive activity. We mentioned before that one of the porphyritic regions comprises the middle part of Germany, while another stretches along the southern slope of the Alps and Carpathians.—If we proceed to the volcanic era, it presents to us the reverse of the individuality peculiar to granitic districts, in the wonderful unity exhibited in regard to time and space over the whole area of extensive belts. In reference to unity of time alone, we might call the greater part of the continent of Europe, and even the entire surface of the globe, one great region of eruptive action, during the volcanic era, since the first emission of rocky matter has been nearly cotemporaneous in widely separated countries, while its culminating epochs have probably varied but little in them separately, and the rocks have been ejected everywhere in a similar order of succession. In regard to local distribution, however, we have to distinguish certain belts, far exceeding in area the porphyritic regions. Each of them extends over a number of preëxisting mountain ranges, and the eruptions in each have followed, in their distribution, chiefly the lines of former elevation and ancient sea-coasts. But there is unmistakably to be recognized a tendency of the agencies which caused the eruptions, to connect these separated ancient belts of elevation; either longitudinally, when ranges superior in extent to the preceding ones would be formed, as appears to have been the case in the Andes; or, as it were, in a lateral sense, when the connection of neighboring mountain ranges into table lands would be either initiated or promoted. One of these belts, consisting of parts which had previously been disconnected, may be traced from Armenia to the Rhine, though I will try to show in the sequel that it is only a part of another belt which is of far greater extent.

We mentioned before, that porphyritic rocks are encountered chiefly in those places where granitic rocks had preceded them. As regards the volcanic belts, eruptive activity has been particularly violent in certain portions of them. It is worthy of note that, wherever this has been the case, either granite or both granitic and porphyritic rocks had been ejected before. This fact leads us to consider the correlation of the three classes of eruptive rocks in reference to their peculiar modes of distribution. Little information exists in regard to this subject. Only one instance[16] shall be related, which is highly suggestive for the existence of such a correlation, though it is of slight value as long as it is not corroborated by corresponding facts observed in other countries. A survey, on a geological map of the Alps and Carpathians, of the southern boundary-line of those highly metamorphosed formations which preceded the Trias in

[16] Referred to in Richthofen, Geognostische Beschreibung der Umgegend von Predazzo, Sanct Cassian und der Seisser Alp in Süd-Tyrol: Gotha, 1860.

age, and chiefly compose the central portion of the Alps, shows that it is directed from west to east in Lombardy, but in the vicinity of Lugano bends suddenly to the northeast, then turns as abruptly back to its former direction from west to east. After having passed the granitic mass of the Adamello, the same change is repeated on a grander scale. The boundary is turned again in a perfectly straight line to the northeast, and then resumes its former course, which it follows in an equally direct manner, and in which it continues, exceedingly distinct at first—less distinct, by the encroachment on it of more recent formations, farther east—until it turns a third time to the northeast at the sudden termination of the Alps near Vienna, and continues in this direction for a long distance. Finally it re-assumes, in the Carpathians, a similar course to that which it had on the southern slope of the Alps. Three very distinct reëntering angles are thereby formed. The first of them encloses the country of Lugano ; the second comprises the vicinity of Predazzo and Fassa in southeastern Tyrol, and of Belluno and Vicenza in Venetia ; while the third, which is by far the most extensive, comprehends all northwestern Hungary. Each of them has been a center of eruptive activity, commencing with the granitic, and continuing through the porphyritic down to the volcanic eras, and all three are among the most classical countries for the study of eruptive rocks. There is, however, a conspicuous difference in the mode of manifestation of the eruptive activity in each of the three eras. Little connection exists apparently between the granitic masses of the three countries. They are portions of the generally scattered granitic outbreaks, and differ among themselves probably as much in age as they do in regard to the nature of their rocks. In the porphyritic era, eruptive activity was contemporaneous in the three localities, but scarcely extended beyond them. In the volcanic era, when the southern slope of the Alps and Carpathians formed only a portion of a much more extensive belt, the countries adjoining those three places were chiefly distinguished by the intensity of eruptive activity.

Great as have been the interruptions between the different eras, the continuance of the selection of those three nooks at the foot of a prominent mountain range for the manifestation of subterranean energy, from Palæozoic down to modern time, is evident. Similar instances, though less striking, might be mentioned from other parts of Europe, such as the porphyritic region of middle Germany. Reverting to other parts of the globe, it appears to be a general experience, though it is far from being absolutely proved, that all the principal accumulations of volcanic rocks are encountered in the neighborhood or immediate vicinity of granitic masses. These are scattered over areas where no volcanic rocks occur ; but the distribution of the latter within any of the volcanic belts appears to have been dependent, in a great measure, upon the vicinity of the channels which had in preceding time afforded vent to granite.

The general law deduceable from these relations is this : that, with the growing thickness of the earth's crust, the systems of fractures which were formed in it at certain epochs, and partly gave vent to the emission of rocky matter, increased in depth as well as in length, and were more and more concentrated to definite portions of the crust, which are recognizable upon the earth's surface by the partly coincident areas of

eruption ; that further, simultaneously with the increase in extent, each area manifested a growing complexity in regard to the distribution of eruptive activity within it, and that this distribution depended in a great measure upon that of the outlets of more ancient eruptive matter. The first recognizable stage of this development, which, however, was probably a far advanced one, is the individualization of those numerous districts of fractures, the narrow limits of which are made manifest by the mode of occurrence of Azoic and Palæozoic granite. A growing development from that stage, in the different directions mentioned, is conspicuous in the porphyritic era in Europe ; when, besides the greater extent of the regions in which subterranean agencies manifested themselves by the fracturing of the crust, every such area had become more definite concerning its boundaries towards those which were not fractured during the same era. On the other hand, however, each porphyritic region was more complex than the granitic districts had been, inasmuch as the former were composed of certain areas of greatest activity, which, as we had occasion to remark, appear to have been chiefly dependent upon the distribution of the granitic districts enclosed within each porphyritic region, while intermediate portions were contemporaneously affected by disturbances merely, but not by any eruptions. A more advanced stage in this gradual development seems to be exhibited by the Jurassic granite of the Andes. The belt distinguished by its eruption appears to have been distinctly bounded, and the area over which contemporaneous manifestations of like character took place, to have been even more extensive than the porphyritic regions of Europe. All these features, however, are conspicuous on a much grander scale in the volcanic era. The growing definiteness of the boundaries of the volcanic belts towards large areas which were entirely free of eruptive activity, the increasing complexity of their interior arrangement, and its dependency upon preëxisting lines of elevation, and particularly on the distribution of granitic and porphyritic rocks, are evident from what has been said before. We may even trace a development from the andesitic to the basaltic epoch. It is known how far superior in extent is the range of basaltic outbreaks to the area occupied by other volcanic rocks. If considered with attention, it will be found that there is a tendency in the former to connect within each belt the subordinate ranges of the latter, longitudinally as well as laterally. The only connection, for instance, between the volcanic districts of Hungary and those on the lower Rhine, is occasioned by the chain of isolated basaltic hills which extends through the central part of Germany.

On the Origin of Volcanic Rocks.

The facts established in the foregoing chapters, and the inferences drawn therefrom, may assist us in considering some questions of wider bearing. We have seen that the volcanic rocks of several, and probably of all parts of the globe, are connected by simple and definite relations, which together comprehend the main features of their natural system ; and we found that correlations of a similar nature ally the volcanic with all the ancient eruptive rocks, justifying, to some extent, the supposition that the eruptive rocks of all ages and places form one harmonious whole, and that we may be

able to discover the laws of the natural system embracing their totality. In order to arrive at a more perfect understanding of this system, we must now attempt to examine into the causes of those mutual relations. It would naturally occur to us that they would be implied in the circumstances which attended the generation of the eruptive rocks, and in the conditions in which they have been before arriving at the places they occupy at present. We have, therefore, to investigate the following questions: What was the nature of volcanic rocks before they arrived at the places which we now see them occupying? Where did they originate? By what agencies did rocks connected in widely separated places by simple and definite relations come to their positions among others which bear no such relations either to them or among each other? The importance of these questions for our subject, the attention which they have attracted through the whole history of geological science, and the great diversity of opinion prevailing in regard to them, will make it necessary to treat them more fully than might otherwise appear consistent with the objects of this paper.

Volcanic action and massive eruptions, notwithstanding the similarity of the material produced by both, would appear, from the most cursory review of the phenomena connected with either of them, to differ to some extent, not only in regard to the causes to which they owe their origin, but also in regard to the position the matter occupied before its ejection. We have for this reason to keep again distinctly separated these two modes of manifestation of subterranean energy. In regard to massive eruptions, which will first occupy our attention, we can scarcely draw up any argumentation without enlarging on the entire range of eruptive rocks, and extending, at least partially, our views to them.[17]

1. *On the Origin of Massive Eruptions.*

In order to establish some positive premises available for drawing conclusions in regard to the origin of the massive eruptions of volcanic rocks, we reiterate the following facts, of which mention has partly been made in the foregoing pages: 1st. The eruptive (including the volcanic) rocks offer a great diversity of chemical composition; but all the compounds represented by them are mutually connected by simple and definite arithmetical relations as regards the figures which

[17] The following considerations are given notw ithout some hesitation, partly on account of the uncertain ground on which they have to move, and partly because some of their main features are, of necessity, only well known theories reproduced, though, perhaps, under a somewhat different form. Yet, the establishment of the relations detailed in the preceding chapters, and other observations made of late years, may allow us to arrive at more satisfactory conclusions in regard to some weighty problems than could be done before, or, at least, to determine more precisely the only direction in which we have to look for their solution. It should be borne in mind that among the theories recently proposed upon the subjects specified above, there is not one which has not already had its prototype in the phantasmagorias of the time of the dawn of geological science, and that it is these which have been constantly reproduced, enlarged, diversified, remodeled according to the advance of science, and supported by continuous accumulation of evidence. Propositions which had been accepted as being beyond the necessity of proof, and which are still occasionally reproduced as axioms in popular works on geology, have been weakened, and not unfrequently overthrown, when facts newly revealed would withdraw their chief supports, but have, after some time, revived under new forms. In treating on a topic where the degree in which the results of our speculation appear satisfactory to us depends upon the degree of probability which we think we see in the theories arrived at, and of their faculty of explaining observed facts, and where we are in constant danger of making incorrect deductions from imperfect premises, not enough can be done in the way of weighing the evidence by which different doctrines are supported; and this is particularly necessary in reference to those theories which we are too much accustomed to consider as matters of fact, upon which further conclusions may be safely built.

express the value of the different ingredients entering into their composition. The law of Bunsen, in which are embodied these relations, though true for all eruptive rocks, has never been applicable to those of sedimentary origin, nor to the metamorphic sedimentary rocks. 2d. The order in which massive eruptions of volcanic rocks have taken place in different countries, is by no means conformable to a regular succession of gradations in chemical or mineral composition, but shows the existence of several distinct groups, each of which comprises, chemically, a certain portion of the entire range of compounds intermediate between the two extreme types, and has, besides, its own peculiarities of texture and mineral composition. It is for the latter reason that rocks, belonging geologically to two different groups, may be identical as chemical compounds, and yet differ petrographically. We may repeat here that these groups, wherever their mutual relations have been made an object of study, occur in the same order of time, and that the rocks belonging to each of them present generally a great similarity in character wherever they are encountered. 3d. The massive eruptions of volcanic rocks are distributed over the globe in certain belts, differing in extent and width as well as in direction.

There are, among those of a general bearing, two manifest conclusions at which we may arrive by the aid of these facts. The first relates to the origin of the matter ejected. It may be said that equality of physical and chemical properties, and of the mode of occurrence, will commonly involve equality of origin. We have, therefore, to infer, that the source from which volcanic rocks have derived their origin has been similar in nature in every locality, that the definite numerical relations existing in the chemical composition of the matter ejected must exist similarly at that source, and that they must there pervade matter equally in different parts of the globe ; and we may further add, that at the same source the different kinds of matter which correspond to the different passages in composition among volcanic rocks, must be arranged, at every locality alike, in a definite order of position in reference to the distance from the center of the earth, since such relation in space can alone explain the definite order of succession in time in which those rocks have been ejected. If we consider the relations existing between volcanic and ancient eruptive rocks, there can be no doubt that all of these have derived their origin from that same source, and that it is of general distribution under the surface of the globe. The second general conclusion relates to the cause and mode of ejection. As like effects imply like causes, and the similarity of the phenomena connected with the massive eruptions of volcanic rocks is conspicuous, we may infer that the agencies to which they have been due, were, in the main, similar in all cases. However accidental and local circumstances may have caused minor differences, the prominent features in the mode of geological occurrence and geographical distribution cannot be due to them. In how far we may be justified to ascribe the ejection of the granitic and porphyritic rocks to similar agencies, will depend upon the degree of similarity of their part in the structure of the surface of the globe with that of the volcanic rocks. The conclusion must be drawn from those correlations which have already been mentioned, that the fundamental causes of all eruptive activity are alike, and implied in general planetary processes which are closely connected with the evolution of the globe. These general

conclusions appear to be the only ones which are fully justified. If we venture to inquire into the nature of the agencies which caused eruptive activity, and to explore their fundamental causes, we have to transgress the limits of legitimate speculation and enter the realm of hypothesis, the only way of proceeding in which consists in weighing probabilities. Further experience, it may be hoped, will extend the limits of induction, in the same measure as it will furnish increased evidence.

I will attempt, in the first place, to consider, what must be the nature, and what the position of the source at which the volcanic and all eruptive rocks have originated, in order that their physical and chemical properties and their mutual relations may be explained, and then to examine what have been the agencies that have had, in all probability, the most immediate influence upon the facts connected with the mode of distribution and succession of eruptive rocks in general. We have to start in these considerations by a well-known argument.

If no changes had ever taken place on the surface of the globe, and no sediments had ever been deposited on it, but that state was still preserved which the globe must have exhibited when the substance of the rocks was liquid on its surface, then the matter nearest to this would probably be of a nearly uniform chemical composition, and, consequently, of a uniform specific gravity. If we imagine the globe to consist of concentric layers, it is exceedingly probable, from physical laws, that then the substance of each successive layer would be, too, of a nearly uniform composition throughout its extent. Proceeding, however, from those layers nearest to the surface to those at greater distance from it, the specific gravity of the matter composing them severally would necessarily increase gradually towards the interior. This would be effected by the tendency of the heavier elements to predominate as the depth became greater, while the lighter would increase in as gradual a ratio towards the surface. If the layers were infinite in number, then the passage, in chemical composition as well as in specific gravity, from the surface towards the center of the earth would be one of infinite gradations. This condition is eminently the most probable, if physical laws are taken into consideration. If the crust was then allowed to solidify, to any depth required, the same interior arrangements would continue to exist unaltered, regardless of any changes on the surface. That a condition similar to this actually exists at the present time, is rendered evident by the well-known fact, that the specific gravity of the mass of the globe greatly exceeds that of the average of the matter which composes its exterior crust. Eruptive rocks have been carried to the surface from places beneath it. The depth from which their material has been derived, the way in which it was rendered liquid, and the cause and mode of its ejection, these are the principal points of conjecture in regard to them. The most probable place of its derivation are those imaginary layers which are beneath the theater of external changes, and still occupy their primeval position. This appears to be manifest from the two facts to which we have constantly to refer: the ejection of identical chemical compounds in all countries and ages, and the exhibition by eruptive rocks, in each country, as well as over the entire globe, of a series of compounds the specific gravity of which increases in inverse ratio with the amount of silica. The suggestion that eruptive rocks, in virtue of these facts, represent the arrangement of matter in the interior of the globe,

those which are rich in silica and of little specific gravity being derived from places nearer to the surface than those in which a smaller proportion of silica is attended by a higher specific gravity, was first distinctly made by Sartorius von Waltershausen, who attempted to prove this theory by mathematical calculation, and has at least succeeded in demonstrating its adaptation to the nature of eruptive rocks. The assumption, hypothetical as it may still appear, has an eminent degree of probability, and is of the highest importance for the geology of these rocks, for the reason that it is capable of explaining numerous observed facts which have failed to be satisfactorily explained in any other way.

We may still draw a line of negative argument in corroboration of this theory. It is perfectly clear that the source of eruptive rocks must either have been below the lowest depth at which rocks of sedimentary origin occur, or above it. We found that the former assumption gave a satisfactory explanation of prominent facts, and it is just as conspicuous that the second fails to give any explanation at all. If eruptive rocks had had their original seat within the crust of sedimentary rocks, and had been generated from their substance, they must be analogous to them in chemical composition, that is to say, they would vary in this respect within very wide and complex limits in any single country, and we should encounter no lesser differences when comparing the totality of eruptive rocks in one part of the globe with that in other parts. The fact that no arithmetical relations can be recognized as connecting the various sedimentary rocks in their composition, would hold equally good among eruptive rocks, since it is impossible to conceive a progress from the indefinite to the definite, from that which is void of any recognizable relations in respect to the composition of matter to that in which such definite relations are plainly evident, by the mere influence of such agencies as would cause fluidity, (that is, the combined action of heat, pressure, and water.) As no agency, indeed, is known to which such a result may be ascribed, this argument removes beyond the limits of probability the assumption, that the original seat of eruptive rocks has been above the foundation of the gradual accumulation of those rocks which have been produced by external changes, and therefore allows only the other alternative, that it has been below that boundary.

While the theory of Sartorius will explain the causes of the prominent mutual relations existing among eruptive rocks in regard to their composition and general similarity in all countries, we have still to trace those causes which effected their ejection from a deep-seated original place to the surface. This question is more abstruse than the foregoing, inasmuch as the manner in which forces have formerly been acting beneath the earth's crust, is a subject more involved, and allowing a larger range of hypothetical explanation, than we met on a field where the observed properties of matter offered a comparatively safe guide. Complicated as the processes appear to have been, to the coöperation of which massive eruptions were due, it seems that they may severally be traced back to one common cause of a higher order, of which all, or most, of them are but different modes of manifestation. Probabilities accumulate to point out as this fundamental cause, the process of the gradual cooling of the earth and the solidifying of its crust toward its interior.

Since the early day of the ingenious speculations of Descartes, this great and general cause has been considered as the main agency to which the disturbances on the surface of the globe are due; and, though having been more or less in favor at different times, the doctrine has at no time been completely abandoned. The various aspects which it has periodically assumed, the latitude given to it on one side, and the objections raised against it on the other, mark one feature of the phases of the gradual progress of science. It has been applied in different forms to explain the mode of origin of ancient eruptive rocks; and, since Dolomieu and, in a more elaborate way, his pupil Cordier, have assigned the same original source to volcanic activity, the contraction of the interior of the globe, by radiation of its heat into space, has been considered as offering a sufficient explanation for the majority of the phenomena which are often united under the term "vulcanism." But, giving all due consideration to the vast effects of which it has undoubtedly been the cause, the conception of the *modus operandi* of this agency (contraction) *alone* meets with considerable difficulty. An outward tension might, indeed, result in the formation of fractures on elevated places; and, supposing for a moment that these fractures would descend into regions where matter was in a liquid state, then the latter might possibly be ejected, and caused to accumulate on the surface. But such would hardly be the effect of an inward tension. It may, too, cause the rending of the crust and, possibly, the filling by liquid matter of those rents which are in the lowest places; but it does not explain the extrusion of this matter to the surface, nor the fact of its particular accumulation on elevated parts of the same. It would take too much of our space fully to detail the numerous mechanical difficulties which occur, if one attempts to explain all the phenomena comprised in the name "vulcanism" by the exclusive assumption of the contraction of the interior of the globe. Some of the more obvious objections against this theory will be briefly mentioned in the course of the following considerations.

A number of facts point towards the existence of some unknown force below the earth's solid crust, which counteracts in a considerable measure the permanent subsidence of the latter by contraction. It is perfectly evident that the secular rising of parts of the surface of the globe above the level of the sea cannot be merely the apparent effect of the different degree of its general subsidence, as has been maintained by very distinguished geologists; but that elevation, that is, the periodical increase of the distance of parts of the surface of the globe from its center, must be a reality. Considering the amplitudes of the changes of level that have taken place in historical time, they will be found to sum up to such figures as, if reduced altogether to subsidence, would indicate a far greater shortening of the radius of the globe within that time, than is compatible with astronomical calculation. It is true that the retardation of the rotation of the earth by the tidal wave must counteract, in some measure, the acceleration caused by any shortening of the radius of the planet; but this retardation is insignificant if compared with the amount of the changes of level. The reality of elevation is forced more directly upon the mind, if those cases are taken into consideration where certain portions of continents are rising above the level of the sea at a more accelerated rate than neighboring regions, which is of very frequent occurrence

in volcanic countries, and conspicuous in those numerous instances where elevation is, or has been in former times, proceeding more rapidly along the crests of mountain ranges than at either foot of them. Adherents of the theory, that all oscillations of the earth's crust are only due to its contraction, consider elevation as real in these cases, and have tried to explain it by the assumption, that folds must be formed by the subsidence of the ample shell on the contracted nucleus; that these folds would increase in amplitude in consequence of a lateral pressure caused by further subsidence, and thus an absolute rise would be effected. It is, indeed, very probable that this process is of vast importance in the formation of mountain ranges; but it cannot explain the total amount of the changes of level. If Fourier's calculation, that, taking the present loss of heat by the globe as standard, the radius of the latter should have shortened seventeen centimeters in twenty-five centuries, is correct, the diminution would have been 1,700 centimeters in 250,000 years, and about six hundred feet in one million years. It is manifest how utterly insignificant would be the corresponding diminution of the earth's circumference, when compared with the vast changes of level which the surface must be supposed to have undergone during such a length of time.

We are bound, for these reasons, to consider, not alone the process of elevation of mountain ranges, but also the secular rise of extensive regions, as realities which cannot be exclusively explained by the contraction of the globe. But if so, there must exist another force, the effects of which oppose those of contraction. The united action of both, and the periodical prevalence of either of them, would then be capable of explaining the alternation of elevation and subsidence at every single place, and the contemporaneous action of both in neighboring regions. This antagonistic force consists, probably, in an increase of volume attending the slow and perfect crystallization of matter, by cooling down, during immense periods, from a viscous state. With a great number of bodies, contraction by loss of heat appears to continue to the very moment of solidification, and to increase during the latter when no time is allowed for crystallization, but to be diminished, and finally reversed, in the same measure as opportunity is given for a slow and perfect crystallization. In the special case of rocks made up of silicates, this must remain a supposition which is not proved, but is eminently probable.[18]

[18] An increase in volume by crystallization has been found, by experiment, to take place in numerous instances, in fact in most cases when a perfect crystallization from a molten state has been obtained, provided that the volume of the substance experimented on could be determined immediately before the act of crystallizing. In respect to those silicates which make up crystalline rocks (not taking into account the water entering into their composition), experiments could hitherto not be made, because it is impossible, with our present means, to allow the viscous mass sufficient time for crystallizing. Yet, there are some suggestive facts which have, in some measure, the value of experiments. We mention among them particularly one which was observed by Ferd. Zirkel in analyzing, with the aid of the microscope, the texture of the minerals participating in the composition of eruptive rocks. He found that "glass cavities" contain ordinarily several of those vacuities which are also exhibited by the cavities filled with water, and have been supposed by Sorby and others to have originated from the contraction, by cooling, of the enclosed matter. If the substance contained in the glass cavities bears signs of an incipient crystallization, by having partly a "lithoid" texture, the vacuities are of rarer occurrence, while they are entirely wanting in the so-called stone-cavities, when the lithoid texture pervades the whole mass filling the cavity. It is scarcely possible to make an experiment more convincive than this natural occurrence, which is more open to subtle observation and measurement than is ordinarily the case with experiments on cognate subjects. It needs hardly to be mentioned, in connection with this question, that those experiments which have been made by Bischof

We may then distinguish as eminently probable, the following immediate effects of the cooling of the globe: 1. Contraction of the liquid portion of the interior, by cooling down to the temperature required for solidification under the respective pressure. 2. Expansion by slow and perfect crystallization. 3. Contraction of the crystallized masses by further cooling. We may add to these as a secondary effect of greatly inferior importance, the flow of heat or change of chthonisothermal planes, at those places where subsidence causes an accumulation, or elevation an abrasion of matter on the surface. This process, to which a truly wonderful importance has been ascribed by some, must be going on continually and everywhere. Being itself the result of motions of the crust, its proximate cause must be the processes attending the cooling of the globe, while in its totality, it may have a further, though very insignificant, effect in shifting the areas of elevation and subsidence.

Other agencies, with which we are yet unacquainted, may probably result from the same common cause. But taking into consideration only those already mentioned, it may appear difficult to form a clear conception of the mode in which they must coöperate, in order not to counteract each other, and thereby to result in a general movement of the crust in one direction only, but to bring about that variety of effects which manifests itself chiefly in the change of elevation and subsidence, and in other modes of dislocation of the crust. It is perfectly evident, that the aggregate effect of those agencies is different under different portions of the crust of the globe, contraction prevailing in some parts, and expansion in others; the former causing subsidence and deposition of sedimentary matter, the other elevation and denudation. But if we consider how gradual is the passage in the state of aggregation from the liquid interior of a current of lava to its solid crust, and if we bear in mind how immensely vaster in volume are those masses which constitute the interior of the globe, and what immensely longer time is given for their cooling and crystallization, the conclusion is irresistible, that the passage in the states of aggregation from solid to liquid must extend there over an immensely greater space. Crystallization will very probably take place next to those portions of the crust which are already solid. If it is attended by an increase of volume, and this increase produces tension, it is very likely that the next adjoining masses, though not yet crystallized, will offer too much resistance to allow this tendency for expansion to find immediate relief by yielding to the general tendency to contraction which may prevail in liquid masses at greater depths. It may thus be explained why, in different parts of the crust, a motion, independent and in opposite directions, may result from the two-fold tension attending changes of volume which take place at different distances beneath the surface, and which

---

and others with a view of ascertaining the increase in volume which different rocks undergo by melting, do not affect our supposition. In the first place, the molten state may be quite different from that in which the same substance would be immediately before crystallizing, and the passage from one to the other may be attended by a decrease in volume which is not counterbalanced by the subsequent increase taking place by the passage of the substance into the crystallized state. Then, the rocks on which the experiments were made had been solidified under a great pressure, while, when in a molten state, they were only exposed to the pressure of the atmosphere. Finally, it has not been ascertained whether all the water which is contained in the rocks does escape on melting or not. If not, then it will probably have the effect of inflating the molten mass.

would oppose, and, to a certain degree, destroy each other, if the state of aggregation of subterranean matter allowed of a free conduct of motion.

These slow and continuous agencies, chiefly those among them which give origin to the process of elevation, must have been, too, instrumental in causing the massive eruptions of rocks. At least, no other force supposed to act beneath the surface can account as fully for certain facts connected with them, such as the gradual changes in the mode of their geographical distribution, or the connection of the manifestations in any certain system of fractures, or the fact that ages of comparative repose have been interrupted by paroxysmal actions of great violence which have taken place during certain eras in the history of each separate country. The latter circumstance points clearly to the assumption, that during the eras of repose, or at least their later portion, a constantly increasing amount of potential energy must have been accumulated under the crust of the globe; since the subterranean agencies called into existence by the cooling of the globe did of course never rest, nor can they be reasonably supposed to have been more intense in the Tertiary than they were in preceding periods. It is self-evident that the increase of tension must have been much more considerable under areas of elevation than under the more extensive regions of subsidence. In the latter case, when a downward tendency is caused by contraction, the weight of the crust must come in its aid; the essence of the resistance to that tendency may therefore be concisely expressed as cohesion minus weight; while weight added to the cohesion will give approximately the resistance to elevation by expansion. The tension under a crust of great thickness must therefore, in the latter case, increase to a stupendous intensity, until it is sufficient to overcome the resistance, and will then be able to result in such paroxysms as that by which the volcanic era has been inaugurated, and the main feature of which consists in the formation of fractures which, by their mode of association, constitute distinct systems or belts, separated by areas in which the existence of fissures in the crust cannot be recognized on the surface.

Although the processes suggested may furnish us the cause for the prime condition to the emission of rocky matter from below, namely, the periodical opening in the earth's crust of such fissures as widened with the approach to the surface; yet they fail completely to explain, by themselves alone, the more immediate causes and the mode of that emission. It may be presumptive to extend speculation upon this topic beyond those limits which we have reached; but a safer guide to conjecture on the same than had been known at any former time was given during the last few years by the experiments of Daubrée, and the microscopic examinations of the texture of rocks by Sorby. It has been held quite generally till of late, that the opening of a fissure to a liquid mass below, would be sufficient by itself to cause the ascending of the liquid through it to the surface;[19] but this supposition is utterly irreconcilable

[19] It must here be remarked that some of the most eminent writers on the subject of volcanoes, chiefly Poulett Scrope, Prof. Dana and others, have suggested long ago, that the ascending of lava in a volcanic channel must be due to both the fluidity and expansion imparted to it by the globular state of the water which finds ingress to the channels of the lava and enters into its composition. They have anticipated, by this suggestion, in some measure, the results of

with physical laws. Supposing for a moment that theory to be correct which considers all the changes of level as originating in contraction alone, then it is quite probable that fissures would be formed in the center of the areas of subsidence. But as they must be closed near the surface, and open in their lower parts, it is difficult to see in what manner the liquid matter could ascend through them to the surface, while no better account could be given for the occurrence of eruptive rocks on high table-lands. In order to explain it, recourse has been had to the most arbitrary assumptions. It may even be read in our time in various geological books, that the crust below might give way from the overload, and the whole be "plunged" into the semi-fluid mass beneath, causing it to overflow. Mountain ranges of a thousand miles in extent have been assumed to subside suddenly upon the liquid mass, and to "splash it out" through fissures. Leaving out of consideration these fantastical theories, there remains a number of others, according to which the weight of portions of the crust would cause the ejection of liquid matter. If the substance composing the crust exceeded in specific gravity the liquid matter below, then this mode of ejection would be probable, and we should be indeed surprised that large portions of our globe were not flooded over repeatedly by molten masses from below. If the specific gravity of the crust and the fluid matter below was the same, then it would require the most extensive fracturing of the crust and uplifting of its fragments, in order to make the liquid mass overflow the latter. But all that we know in regard to the subject goes to show that the masses below the crust are of greater specific gravity than those composing it. To suppose the weight of the crust to cause the protrusion of liquid matter through fissures, is therefore to suppose an action which is mechanically impossible.

We arrive at no more satisfactory conclusion in regard to our present problem, if, besides the contracting forces, we assume the existence, beneath the crust of the earth, of others which have their origin in the increase of volume by crystallization, and thus produce expansion. I attempted to show that they furnish the most probable agent to which may be ascribed the opening of the systems of fissures, which partly served as the channels for the extrusion of rocky matter. These fissures would have to be open at the surface and to decrease in width below, because formed by an outward tension on areas of elevation. It cannot be assumed that they would descend to any greater depth than the lowest limits of solid rocks; they would, therefore, not reach down to any matter sufficiently liquid as to be capable of being forced up through them. And if it should be able to ascend, then it would solidify within the fissure, almost instantly, by loss of heat, and long before reaching the surface. There is, however, even a more forcible argument to demonstrate why it should not have been capable of ever entering the fissures. For, if our supposition that the silicious masses beneath the crust increase in volume by crystallization is correct, the relief from pressure by the formation of fissures must have the immediate effect of rapidly pro-

experiment established by Daubrée. But the supposition was only made for the case of lava, and not for that of rocks which were ejected without volcanic action proper. Yet even in regard to volcanoes it did only explain the extrusion of lava to the surface from a place at a limited distance below it, and failed to give a clue to the manner in which the constant supply of matter to those places was kept up.

moting the crystallization of vast masses which had been held in a viscous state before, by the existence of the tension itself. It needed, for all these reasons, another agency which would not alone force up molten matter through the fissures, but also cause it to arrive at the surface in that particular state of aggregation which it has had, according to the observations of Sorby. This agency is indicated, by the experiments of Daubrée, to have been water, the descending of which into the fractures is indeed a necessary consequence of their formation. There it would convert the state of aggregation of the masses surrounding the lowest parts of the fracture into that called by Daubrée "aqueous fusion," which appears, indeed, to have been the state in which all eruptive rocks have been immediately before their consolidation. The process of aqueous fusion, as has been shown by the same eminent geologist, is attended by a very considerable increase in volume of the masses affected. It would, therefore, give rise to processes totally different from those which had preceded. For this expansion would immediately cause a motion of the masses rendered liquid, in the direction of least resistance, that is, upwards in the fissure, and would, if continued for a sufficient time, make the same overflow on the surface of the crust, even if unassisted by other ejecting agents, such as the vapor of water.[20]

We may carry these deductions still further, if we revert to our previous conclusion, that the relief from pressure by the fracturing of the crust would have caused the crystallization of masses below it, which had been held before in a viscous state by the tension itself. This process would extend in depth as well as laterally, and gradually affect the viscid masses beneath an entire belt of fissures. It would have had again to be attended by an increase of volume. But those crystallizing masses not being in a state of aqueous fusion, the resistance could in this case not be overcome by the extrusion of that portion of them by which they were increased in volume, and the effect would be, as in the case first mentioned, accumulation of potential energy. I will attempt to

---

[29] If we consider the geological features of all large accumulations of eruptive rocks, such as the great andesitic ranges of Hungary, or the quartzose porphyry composing a plateau of great dimensions in southern Tyrol, or those granitic masses which, by overlying the edges of stratified rocks, give evidence of having been ejected to the surface in a liquid state—it would appear that their emission has been a slow and mainly a quiet process of long duration, hardly attended by those convulsions and paroxysms which form the prominent features of volcanic action, and should have been no less characteristic of massive eruptions if they had been due in any large measure to the expansive force of vapor. The process of the emission of the rocky matter has, it is true, been evidently intermittent in most cases, as may be inferred from the occurrence of vast accumulations of breccia, and it appears that an extensive solfataric action has frequently taken place through neighboring fissures; but the manner in which the matter was protruded through the main fissures and deposited on the surrounding parts of the surface, had evidently no similarity to the mode of ejection of scoria, ashes, and lava from most of the active volcanoes. The mode of action described, which may be inferred from geological observation, is perfectly in accordance with what we should expect it to have been by reasoning *à priori* on the basis of our previous suppositions. For, if G. Bishof's calculation is correct, that the elastic force of steam is at its maximum when it has the same density as water, which it would acquire under a pressure of 8,300 atmospheres, the loftiest column of lava (taking its mean specific gravity to be 3) which should be supported by it, would be, according to Jukes, 88,747 feet. The original seat of those eruptive rocks which were protruded without being accompanied by volcanic action, must necessarily have been at a much greater depth, and we should therefore, also from this point of view, be led to suppose that the expansive force of steam has had only an insignificant part in their protrusion from greater to lesser depth. It must, of course, have come into action when the liquid masses arrived near the surface, but will have caused hardly more than an ebullition, even in viscid masses, on account of the extent of the openings. The formation of conglomerates could thereby be vastly promoted, but their final deposition and consolidation must have been quite different from the manner in which similarly subdivided matter would be deposited around a volcanic orifice.

demonstrate in another chapter that the changes of level which have been connected with the ejection of rocks, appear to confirm these suppositions. Suffice it here to draw the necessary consequence, that the increasing tension must finally have had the effect of rupturing the newly consolidated masses. If in the intermediate time the masses filling the fissures of the first epoch had, at least partially, been consolidated, then a new system of fractures would be opened, within the limits of, though not coinciding with, the first. These fractures of the second epoch would descend to greater depth than those of the first, and in allowing the access of water to masses situated in lower regions and being of a more basic composition, would open for these the way to the surface. By the repeated occurrence of this or similar processes, the theater of action from which the rocky masses were conducted to the surface, might descend, by steps, into considerable depth within a comparatively short period, and thus there could be produced a great diversity among the rocks emitted through one system of fractures, though this diversity would be regulated by definite relations in regard to the nature and succession of the rocks ejected. The process would come to an end when the solidification of matter and the formation of fractures had descended to those masses, the state of aggregation of which was such as no longer to allow them to crystallize when the pressure was diminished, and in this way any further increase of volume would be prevented. The matter filling the fractures would now solidify, and the communication of the interior with the surface be cut off, with the exception of the volcanic channels. The resistance offered by the crust of the globe would hence be greater than it had been before, and there would follow another era of repose, longer than that which had preceded the era of eruptive activity.

The application which may be made of these processes suggested by theory, to the explanation of the actual correlations of eruptive rocks in regard to their age, chemical composition and geographical distribution, is obvious. We may, indeed, venture to deduce *à priori* the history of eruptive action, in its main features, from the hypothesis of Sartorius, and the assumption that silicates will increase in volume by perfect crystallization. We should have to conclude that in a remote period, when the crystallized crust and the sedimentary shell of the globe were inferior in aggregate thickness, fractures and eruptions of rocky matter would have been of frequent occurrence, and that highly silicious compounds should have prevailed among the ejected masses. Little, if anything of them, is probably visible at the present surface, as the rocks of the Azoic and Palæozoic formations are probably the monuments of an already far advanced stage of the development of our planet. All the distinguishing features of the eruptive rocks of these periods (including of the Palæozoic age only the Silurian and the first part of the Devonian), such as the great number and individualization of the granitic districts, the independence of each of them in the subtler differences regarding the commencement and further development of the eruptive activity as well as the peculiar nature of the rocks ejected, the great preponderance of highly silicious compounds, the common association with them of small quantities of basic rocks, and the slight increase of the proportion of the latter in the Devonian period—all these phenomena are easily understood, without further explanation, in the light of our hypothesis.

Let us now direct our attention at once to the volcanic era. The conditions of the globe must have been very different in the Tertiary from what they had been in the Palæozoic period. A longer time of comparative repose had in most parts of the globe preceded the inauguration of the violent manifestations of vulcanism in the Tertiary period than had ever before elapsed between any two eras of eruptive activity. The globe had cooled down. Volumes of sedimentary matter had accumulated, and added externally to the thickness of its crust, while it had increased in a vastly greater measure by the crystallization of liquid matter below. Those silicious compounds especially, of low specific gravity, which had formerly yielded the material of the vast accumulations of quartziferous eruptive rocks, would have been consolidated, and the limit as it were between the solid and the viscous state of aggregation receded into regions where the matter would be of a less silicious composition and of greater specific gravity. The similarity in distant countries of the rocks first ejected (propylite and andesite) goes to show that the recession of that limit into greater depth must have proceeded in a nearly equal ratio in all those regions where volcanic rocks are distributed. When the tension below had increased sufficiently to overcome the resistance, it would now no longer manifest itself in the formation of small and differentiated systems of ruptures. In the direct ratio of the increase of the resistance the fractures would have to be of greater extent, and those elongated belts of them would be formed which even now are partially distinguished as the belts of volcanic activity. The first rocks ejected would necessarily be of a more basic composition than the predominant rocks of the granitic era, while the repetition, at a later epoch, of the process of fracturing would give rise to the ejection of rocks in which silica would be contained in a still lower proportion. The greater portion indeed of the ejected rocks consisted of propylite and andesite, in the first, and of basalt in the second half of the volcanic era. A notable but only apparent anomaly in the regular order of succession has been the emission of trachyte and rhyolite between the andesitic and basaltic epochs. But if it is considered that these rocks were ejected partly from the same fractures through which andesite had ascended, and partly from others in their immediate vicinity, while the distribution of basalt has been independent, to a certain extent, of all foregoing eruptions, it is evident that the occurrence of trachyte and rhyolite is closely dependent on that of andesite, and bears only a very remote relation to basalt. It appears that after the ejection of the chief bulk of andesite, when other processes ending in the opening of fractures into the basaltic region were being slowly prepared in depth, the seat of eruptive activity ascended gradually toregions at less distance from the surface. There is, within the limits of conjecture based on physical laws, no lack of processes which could coöperate to that effect. The consolidation of the ejected masses within the fissures would probably proceed simultaneously, by loss of heat, from the surface downwards and, by pressure, from below upwards. The opening of new branches from the main fractures, the remelting (by the aid of the heat of the molten mass within the latter, and of water finding access to it) of solidified matter adjoining the fracture, the emission of that remelted matter through those branches: all these are secondary processes depending on the first almost necessarily. The supposition that to these is due the

order of time in which trachyte and rhyolite have been ejected to the surface, is corroborated by the fact that these rocks occupy generally a subordinate position in regard to quantity, and have had, to a great extent, their origin in volcanic action. When treating about the latter, we will come back upon this subject. There remain some peculiar features of volcanic rocks which cannot be satisfactorily explained at the present time. We mention, among them, the fact that the three modes of texture of rhyolitic rocks are often severally limited to certain localities; the mode of formation of the laminated structure of rhyolitic and trachytic rocks; the occurrence of the compounds of hornblende and oligoclase in that threefold form to which we have repeatedly referred; the fact that basalt has been followed only to a very limited extent by rocks bearing to it a similar relation, as trachyte and rhyolite do to andesite.

As regards the long lapse of time intermediate between the Devonian and the Tertiary periods, the mode of occurrence of eruptive rocks in the same shows in nearly every respect a gradual transition from that which was peculiar to the granitic to that which we just described as being characteristic of the volcanic era. This intermediate period may be designated as the porphyritic era, though this name appears to apply more properly to its first part only. Quartziferous rocks were not so predominant in it as in the granitic era, porphyrite and melaphyr having nearly equaled quartzose porphyry, in point of quantity. Augitic porphyry was ejected in a much larger proportion to the aggregate bulk of the porphyritic, than diabase to that of the granitic rocks. Where it occurs, it was the last in the order of rocks erupted, while quartzose porphyry was generally the first among them, though this place is sometimes occupied by porphyrite. In reference to the general features of their geographical distribution, porphyritic rocks occupy no less distinctly an intermediate position, as may be seen by what we have said on this topic on another page.

There are exceptions to the order of general development as here specified. They regard chiefly the texture, and are almost exclusively to be found among the rocks of the porphyritic era, though the recurrence, in propylite, of the properties of ancient diorite, is a phenomenon of a no less exceptional nature. Leaving this rock (propylite), or rather only some of its varieties, out of consideration, the volcanic rocks have their peculiar characters, by which even the most basic rocks are to be recognized when seen in large accumulation. In the rocks of the granitic era, if we consider its end to be within the Devonian period, the characteristic features of porphyritic and volcanic rocks are probably never to be observed. Among the exceptional occurrences within the porphyritic era, may first be noticed the fact that perfect granitic texture is still occasionally encountered, as, for instance, near Predazzo and on the Monzoni in southern Tyrol, where some subordinate masses of rock resembling granite and syenite have been ejected in the Triassic age, together with the well-known porphyritic rocks of that region. There are similar instances known from other places on the European continent, but they are scattered, and the respective rocks always quite limited in extent. The grandest exceptional instance that is known up to this time, is the recurrence in the Jurassic period of perfect granitic texture in the eruptive rocks of the Sierra Nevada. But as regards their mineral composition, these rocks belong to the family of syenitic granite, containing hornblende as a very characteris-

tic ingredient, while silica enters into their average composition probably in a much lower proportion than it is contained in ordinary granite. The varieties known as granitite are of rare occurrence. In another respect, namely, the mode of geographical distribution, the Jurassic granite of the Andes marks an advanced stage, if compared with the Permian and Triassic porphyries of Europe, inasmuch as the area of its distribution excels the porphyritic regions of the latter continent in regard to their extent and the unity of their inner relations, while it does not come up, in these respects, to the properties of the great volcanic belts.

2. *Origin of Volcanic Action.*

I have tried to demonstrate in another chapter, that volcanic activity is intimately connected with massive eruptions in a three-fold way, namely, in respect to the epoch of its commencement, the mode of its distribution, and the nature of the rocks ejected. Basaltic volcanoes occur in ranges built up by the massive eruptions of basalt, or in their vicinity, in such connection as to make obvious the nearly contemporaneous origin of both. Andesitic volcanoes are found in the neighborhood of those masses of andesite which had been ejected without being attended by volcanic action; while volcanoes which have emitted rhyolitic or trachytic lava are so situated as to justify the inference of a close connection between the first opening of their vents and the origin of neighboring accumulations, either of rocks of similar character or of andesite, but which are due to massive eruptions.[21]

No distinct line of demarcation can be drawn between the two modes of mani-

[21] This affinity in regard to petrographical character and geographical distribution is probably the cause why both agencies have ordinarily been confounded. It has been a current notion, strongly advocated at times, that all volcanic rocks have come to the surface in a similar way to that in which lava is being ejected from volcanic vents, and that the cause of the ejection has been the same in all cases. In regard to the fact that extensive mountain ranges are completely built up of volcanic rocks, it was argued that it is by no means necessary, and in fact erroneous, to suppose them to have originated in events surpassing in magnitude those of the present day, as the length of geological time would explain how they could be built up by the gradual accumulation of innumerable currents of lava. Where traces of former volcanic vents could not be found, the easy destructibility of the matter of which the sides of craters are usually composed, afforded a convenient and apparently just argument for explaining their absence by denudation. The same doctrine was applied for explaining the mode of formation of ancient eruptive rocks where we see mountain masses made up of them, while others have arrived at the conclusion that they were the "roots" or "cores" of volcanoes; granite itself is by them considered to have had formerly, and to have now this function, even in the case of those volcanoes the lava of which consists of basalt. Both these doctrines have been adopted the more readily, as they appear to be in harmony with the favorite hypothesis, that at no time have any changes on the surface of the globe been more violent than those going on at the present day, nor different from them in mode. However ably this theory, which contributed so much to the advancement of science by checking the phantasmagorias of former time, has been advocated, an unbiased comparison of the grand manifestations recorded in the geological structure of an andesitic mountain range, with the mode and degree of activity of present volcanoes, must lead to different conclusions. In the endeavor to sustain the *à priori* assumption of the equality of force in all ages, too little stress has been laid on the circumstance, that, however nearly equal the aggregate amount of force acting on the globe may have been, its modes must have undergone a change, chiefly by the partial conversion of the heat of the globe into other forces. At the same time, the degree of the intensity of the manifestations of subterranean forces must have varied in a two-fold way. With the continuous increase of resistance, the aggregate motions of the crust must have decreased, since a growing amount of these forces was required for overcoming the resistance. On the other hand, the manifestations of the same forces had to become periodical and paroxysmal, and periods of violent action had to be separated by others of repose. The violent activity of the Tertiary period has passed, and our present volcanoes appear to mark the transition into another period of repose. I will try to demonstrate that the causes of their action are utterly inadequate for explaining the grander phenomena and correlations of massive eruptions.

festation of subterranean energy, as some of the monuments of the grand volcanic action of the past indicate the former existence, at certain places, of a stage intermediate between both. But in those numerous instances where the nature of either of them can be distinctly recognized, some conspicuous differences may be noted between them. Volcanoes are provided with a channel connecting the seat of volcanic action with the surface. The matter which they eject consists either of stratified layers of ashes and scoria, or of currents of lava in the shape of flat sheets superimposed over one another, or of alternating layers of both kinds of material, the latter structure being most frequent. A low dip, verging on horizontality, of all planes dividing substances of dissimilar nature, or marking successive deposition, and homogeneity of material parallel to those planes, together with a structure of the mountain masses distinguished by the radiation of all mineral matter from one common center, may be considered as those features by which even extinct volcanoes, or fragments of them, may unmistakably be recognized. The center may shift, or have shifted, within narrow limits, or a series of centers may follow each other in close succession, but this will obliterate the true character only in a slight degree. Similar rocks, when they came to the surface by massive eruptions, do not present these distinguishing features. They usually compose ranges of small width in proportion to their length, and in the place of one or more distinct centers an elongated axis may be detected, from which the structural and morphological features originate. As regards the interior structure, there may be observed a certain massive character of the rocks, which is partly produced by the prevalence of their compact varieties, and partly by the circumstance that homogeneity of lithological character may be traced to a great distance in a vertical direction. In sections, masses are frequently found thousands of feet in height, which do not vary perceptibly in character, and show no horizontal structure. If the slopes of the ranges are examined, the rocks will be found preserving a homogeneous character chiefly in a direction parallel to the axis, while it is less persistent at right angles to the latter. The planes dividing dissimilar rocks are inclined at all angles, and have very frequently a steep or nearly vertical position. Breccias even, which sometimes occur in very large masses, are bounded in this way towards the adjoining compact varieties; they are of irregular shape, and do not often occur in stratified layers or in elongated currents, as is the case when they are produced by volcanic action. The ranges made up by massive eruptions show no signs of craters. Yet they are frequently the foundation of volcanoes. Oftener still do volcanoes occur on the lower portions of their slopes, or they may form a series parallel to the axis of the main range, and even greatly exceed it in elevation.

Notwithstanding these points of difference, there are not only stages of transition between the distinct geological features resulting from either mode of action, but a similarity in character may be produced under certain circumstances, which makes it difficult to decide what was the mode of origin of an accumulation of volcanic rocks. In the first place, the matter extruded through fissures may have been so liquid as to expand at once in thin sheets. This is very frequently the case with basalt, in the great accumulations of which, whether they be due to massive eruptions or to volcanic activity, the prominent differences wrought by both modes of action in the external

features are generally least conspicuous. This basic compound is not only more fusible than the more silicious rocks; but, it appears that the admixture of superheated water will increase its fluidity more than that of the other compounds, while those unknown influences which cause the mass to solidify in the particular form of basalt must be still more potent in increasing its fluidity, since lavas consisting of dolerite, leucitophyre, and trachydolerite, which are quite or nearly identical with the former in chemical composition, are never so liquid as those of basalt, and are not unfrequently quite viscous. These rocks, together with all those of a more silicious composition, exhibit more distinctly the differences in origin, and this is probably due, in a great measure, to the peculiarity just mentioned. The great fluidity of basalt, which is also made evident by its frequent occurrence in very thin and yet very extended dykes, causes it, even when confined in the narrow space of a volcanic vent, to let the vapors of water escape, in quiet ebullition, in its orifice, as Dana has so beautifully illustrated in his description of Kilauea, while, at intervals, it will break out and cover the surrounding country with flat sheets of lava. The action connected with the ejection of the same rock from larger fissures, in former time, appears to have been similar to this. Yet, the numerous instances of the occurrence of basaltic cinder cones, and, on the other hand, of large accumulations of solid basalt with no perceptible horizontal structure, go to show that also in the case of this rock the modes of occurrence may be different when they are the result of different modes of ejection. Other instances of a similarity of the manner in which the matter has been deposited, when due to either mode of ejection, are frequent on the flanks and at the ends of the andesitic ranges of Hungary, where currents of andesite as well as of rhyolite have been emitted through fissures in andesite, at little elevation above the foot of those ranges. They appear to be due to processes intermediate in kind between both modes of ejection. We may, finally, mention those cases where massive eruptions were sub-aqueous, and layers of fine-grained tufa formed, alternating with coarser conglomerates, between which may be intercalated solid layers of the same kind of rock of the fragments of which those are composed. The similarity of this kind of depositions with the sediments of submarine volcanoes is often very great.

The principal point of difference between massive eruptions and volcanic action appears to be the depth of their source under the surface, and all the minor differences are probably dependent upon that. The region from which the former have derived their material, is, as we tried to prove, at a great depth beneath the deepest sedimentary rocks. The seat of volcanic action appears to vary within wide limits in regard to its distance from the surface, but to be, on an average, at much less depth than that of the massive eruptions; though there are circumstances which render it probable that it is in all cases beneath the shell composed of sediments. Evidence has been gathered by Prevost, Dana, Scrope, Hopkins, and others, in favor of the assumption that volcanoes are not connected with the molten interior of the globe, and are therefore not to be considered as safety-valves. The comparatively little distance of the seat of volcanoes beneath the surface is rendered particularly evident by the small area of the earthquakes attending their activity, when compared with the wide extent of others which must be dependent on some deep-seated action, but have no recognizable con-

nection with any particular volcanic vent. It is no less obvious from the fact that two neighboring volcanoes may not only eject, contemporaneously, different kinds of lava, but also be, to some extent, independent of each other in their manifestations.

We may base further conclusions in regard to the origin of volcanoes upon the following premises, which we repeat from the foregoing pages: First, several facts appear to indicate that the source of volcanic action is at a comparatively limited depth; second, all volcanoes, whether active or extinct, are intimately connected with massive eruptions; third, this connection is of such a character as to establish, in the majority of cases, the close similarity and chemical identity of the mineral matter ejected by the volcano in its first epoch of activity with that of neighboring hills or of its own foundation, which had been accumulated by massive eruptions; while in other cases these neighboring hills or the foundation of the volcano are composed of volcanic rocks not identical with the lava, and then the latter will belong lithologically to a kind of rock which, according to the order of succession of massive eruptions, would be of a more recent origin than the former; that is, trachytic or rhyolitic volcanoes were frequently opened at those places where only andesite had been accumulated before, and basalt where either andesite or trachyte had preceded; but the reversed order appears not to occur, no basaltic volcano having been succeeded, in its own neighborhood, by massive eruptions of trachyte or andesite; fourth, many of those volcanoes which have been active through a long period, have undergone a periodical change in regard to the character of the mineral matter ejected by them, and this change is in general (though with exceptions) conformable to the order of succession observed in regard to massive eruptions.

From these facts may be inferred the complete dependency of volcanoes upon massive eruptions. The latter, as we attempted to show, were due, firstly, to the opening of systems of fissures which extended throughout the solid crust; and secondly, to a quiet outflow, which was caused by the expansion attending the change of aggregation of solid or highly viscous matter around the lowest part of the fissures into that of aqueous fusion. The relations of volcanic activity to massive eruptions are indicative of a process by which the elongated and extensive vents of the latter were gradually differentiated into isolated and narrow channels feeding isolated orifices on the surface. It has been observed that cinder eruptions mark generally the last stage of volcanic action. We may go a step further back, and say that volcanic action is the last stage of massive eruptions.

In order to arrive at a conception of the manner in which the change from one mode of action to the other could be effected, let us suppose that a main fissure was filled with matter from below, and mountains of volcanic rocks accumulated above it by the long continued overflow. Solidification would at once set in, and proceed downward whenever a cessation of the extrusive action occurred, independent of the question whether it would not simultaneously proceed upwards from the depth. Its progress would not be equal in all parts of the fissure, since this must be wider at some places, and more contracted at others. In this condition we should have one of the causes for the isolation of centers of action, for the length of time during which different portions of the matter would remain in a fluid condition, must, of

course, depend in a great measure upon the width they would severally occupy within the channels, and those filling its wider parts must for a longer time remain susceptible of renewed expansion by accidental circumstances. Another cause which would have the same general effect, is the localization of the ingress of water. Some of its channels would, to all probability, become obstructed, and the rate at which new ones would be opened in their place would probably diminish in nearly equal ratio with the total amount of the manifestations of energy connected with the phenomenon of ejection in its different stages. As it appears that the supply of water, which may be either constant or intermittent, is, next to an elevated temperature, the chief condition for entertaining volcanic action, it may be inferred that the cause mentioned would contribute greatly towards the isolation of certain portions within the main fissure, by helping to keep the matter within them in a liquid state. If this second cause was coincident with the first, by the restriction of the ingress of water to a place where the fissure expanded, then both circumstances would combine to prolong the state of liquidity at that point. The connection between the bottom and the surface may have been kept open in a certain part of the mouth of the fissure, while solidification was proceeding over the rest of it. An isolated vent would then gradually be formed, and narrowed down to the size of a volcanic orifice. Obstructions of the outflow, by periodical consolidation, would become more frequent, and thus would proceed a slow change of the mode of action of massive eruptions to that which is peculiar to volcanoes.

This is probably the simplest manner in which volcanoes can originate. It will apply particularly to a number of those which have undergone no change in regard to the character of their lava, and the lofty cones of which rise over mountain ranges consisting of the same material with their own lava and cinders, though owing their origin to massive eruptions. We must now consider a third cause which would aid in promoting volcanic action, and probably come very often into play. It is indicated by the frequent occurrence of series of volcanoes extending in lines parallel to the axis of the main outbursts. Their only possible cause is the formation of fractures, parallel to the main fissure, and branching off from it. In order, however, that these could be formed, solidification must have proceeded downward in the main fissure, without any communication with the liquid portion in depth having been kept open. This process would necessarily imply a temporary cessation of the process of extrusion. That this could take place may be the more readily understood, if it is taken into consideration, that the liquid masses filling the fissure in its whole extent must contract considerably by constant loss of heat, and that any additional expansion produced by the promotion of aqueous fusion at certain places had first to equalize this loss of volume, before it could manifest itself in a rise of the whole mass. This twofold action, which is probably one of the main causes of the intermittent character of volcanic activity, must produce an alternating motion of matter within the fissure, and there would be given ample opportunity, during a period of its subsidence, for the consolidation of the upper portion to a great distance down from the surface.

If a period then followed in which, by dislocations of some kind, a change took place in the conditions subterranean, and expansion began again to prevail within the fissure, the new supply of force would manifest itself at the upper limit of the liquid

portion, where the least resistance was offered, and new fractures would be opened branching off at that depth from the main fissure. The liquid matter would ascend through these secondary fractures, and, if these were of sufficient dimensions, give rise first to the formation of parallel ranges of volcanic rocks by massive eruptions, and then only to a gradual isolation of channels of volcanic action, as in the case first explained; or, if the fracture consisted of a series of smaller ruptures, cause at once the formation of a series of volcanoes. The activity in these secondary fissures could continue long after any manifestations had ceased over the main fissure, and even after the consolidation of the matter contained in this, with the exception of the volcanic hearths, had proceeded into far greater depth. The formation of secondary fractures, branching off from the main fissure, might be repeated at different depths, and fissures of a third order be formed, branching off from those of the second. Subterranean reservoirs of liquid matter, which may either be isolated or connected, would thus be formed at different depths, and be arranged after a similar plan below ground, as we notice among the active and extinct volcanic orifices above ground. The hypothesis of the existence of such subterranean seas of melted matter, as they have been called, has also, though in a very different meaning, been arrived at by the adherents of the theory of a metamorphic origin of volcanic rocks. This coincidence increases the degree of its probability. But unless the nature and distribution of those reservoirs is made dependent on grander phenomena having connection with the interior of the globe, they will not be capable of explaining the harmony prevailing either in one volcanic region or between all these regions. We have been led, by arguing on our suppositions, to the same conclusion at which we arrived before by induction from observed facts, namely, that the seat of volcanic action must be at a comparatively limited depth. Yet it appears that this depth is in all cases below the shell of sedimentary rocks. Among the reasons supporting this assumption, we mention only one. This relates to the chemical composition of lava. The volcanic is typically the era of andesitic and basaltic compounds. The occurrence of trachyte and rhyolite among the ejected rocks goes to show, that the seat of action receded at certain places from the andesitic regions to those of the compounds corresponding in chemical composition to the two kinds of rock named. But if it had been partially above those regions where matter is still in its primæval position, then we should expect that there would be volcanoes the lavas of which, being derived from sedimentary rocks, would, as a whole, deviate in composition from the law of Bunsen. No such volcanoes are known, and it is, therefore, not probable that the seat of any of those the lava of which has been analyzed is within the shell of sedimentary rocks. It is true that subordinate deviations from the composition as required by theory occur; but it has been found sufficient to ascribe them, as in the case of Vesuvius, to a mechanical destruction of the rocks surrounding the channel of ejection by the ascending lava.

Active volcanoes themselves furnish an illustration in evidence of their own origin as here advocated. It is well known that small cones are frequently met with on the slopes of larger volcanoes. If they occur in larger number, as on Mount Etna, they are usually situated in lines which radiate from the crater. Each of them is built up of layers of scoria and ashes sloping away from the center, where a crater is im-

mersed, and such cones will occasionally emit currents of lava, and be in fact the repetition on a small scale of the mother volcano. The usual and probably correct explanation of their mode of occurrence is this: That, through crevices or by passage through porous rocks, water gets access to glowing lava, and, by its action on the same, causes the opening of a fracture, and, in immediate succession, the repetition of the same phenomena which the mother-volcano presents when active. Just as these parasitic volcanoes have their roots in the glowing lava, volcanoes in general must, as is demonstrated by their mode of occurrence, be considered as parasites on certain subterranean portions of the material of massive eruptions, which still possess a high temperature and are kept in a liquid state by the molecular combination with water which finds access to them. This mode of origin of volcanoes, however, is only a repetition on a small scale of the manner in which massive eruptions themselves originated, inasmuch as volcanoes bear a similar relation to the latter as these do to the primeval substance composing the interior of the globe, to which the fractures descend. These main fissures, which are probably very few in number in every volcanic belt, form the great arteries in this harmonious system. Their common origin will furnish an explanation of the general similarity of the phenomena presented by different volcanic belts; while the varied and possibly very intricate mode of their ramifications towards the surface, together with the different conditions of the rocks which they intersect, the various rate and local diversity of the access of water, the different circumstances which may determine the depth in which the expansive force of vapor can be brought into action (among these may be the relative proportion in which chlorine, fluorine and sulphur are present), and other influences unknown, would give ample means for explaining the diversity of all the phenomena of vulcanism within each separate volcanic belt: such as the apparently intricate, and yet to a certain degree harmonious, mode of distribution of the rocks ejected; the correlations existing among the latter in regard to their composition; the dependency of volcanic action on massive eruptions; the mode of distribution of hot springs, solfataras, geysers, and other phenomena which were apparently associated with both modes of action; the different phenomena connected with the occurrence of earthquakes; the small size of their area of disturbance when connected with volcanic action, its varying, and sometimes very great extent in other cases where no connection with any one distinct volcano can be discovered; the singular correlations, finally, which have been observed to exist between different volcanic vents situated on the same belt. Some hints may even be got in regard to the remoter correlations which apparently exist between the phases of volcanic action on neighboring belts, though it must be conceded that in respect to the latter numerous facts have been observed which cannot be satisfactorily explained in the way here proposed, and rather appear to indicate the influence of the phases of magnetic currents on the manifestations of vulcanism.[22]

[22] An extremely valuable contribution to the elucidation of these correlations respecting the phases of volcanic activity was lately given by Dr. Emil Kluge, in his work, *Ueber den Synchronismus und Antagonismus von vulcanischen Eruptionen, Leipzig*, 1863. The clear and able compilation of facts will be of lasting interest, though grave objections may be raised against the author's views on the origin of volcanic action, which are not based on any inferences drawn from the correlations demonstrated in the same book.

The foregoing considerations may explain what appears to have been the most probable way in which volcanic activity was developed at and near the places of massive eruptions. They apply without difficulty to those cases where volcanoes have undergone no change in regard to the character of their lava. We have still to consider those more intricate cases where the latter has periodically changed. There are volcanoes which exhibit a regular succession of andesitic, trachytic, and rhyolitic lavas, followed in a later period by the outpouring of basaltic lava, either through the same, or through other vents in the immediate vicinity. There are others in which only a part of this series can be observed, such as the succession of basalt to trachyte or rhyolite, which appears to be of the most frequent occurrence, or of rhyolite only to andesite. As the order of succession is generally the same as that exhibited by massive eruptions, it would appear that it must be due to the same causes in both cases. If we take it for granted, that those extensive reservoirs of melted matter, from which was either continued its quiet protrusion, or volcanoes were fed, have had their seat in those concentric layers of the crust composed of silicious masses which correspond to trachyte or rhyolite in composition, then there is little difficulty in explaining the protrusion of portions of them. For there must be a limit to the expansion of a substance such as a given mass of andesite, by aqueous fusion, and thereby a limit to its ejection. The eruptive activity might then either come to rest or continue. As it is very improbable that water takes originally a part in the composition of those masses below the shell of sediments which have crystallized from a molten state, its access to them at places contiguous to a source of heat, such as must be given by a fissure filled with molten matter from below, must be attended by a powerful influence on them. It would exert itself in aqueous fusion and expansion. But the viscidity peculiar to these highly silicious substances would not allow their extrusion until after the more liquid andesitic masses had been ejected. Supposing the reservoir in which this first change was effected to have been in the trachytic region, further action from the same could be cut off by the cessation of the ingress of water to it. Another reservoir, situated in the rhyolitic region, might then be isolated within the educting channel, filled now with trachytic matter, and the same process repeated, as before, ending with the change of trachytic into rhyolitic rocks. As regards the succession of basalt to these silicious rocks, we refer to the fact established before, that the fissures which gave vent to basalt, have all been formed at a much later epoch than those through which andesite had ascended, and that they were only partly coinciding with them. It would appear that subterranean reservoirs of liquid matter, connected with the surface by channels of ejection, should have offered, in many cases, the places of least resistance. It may, therefore, be inferred, that basalt, the great comparative liquidity of which is a well-known fact, would enter many of those reservoirs, and be emitted through the same, or through newly-formed channels, in preference to any matter of a more viscous consistency; and it will not be difficult to understand why basalt should, in many instances, have again been followed by, or alternated during long epochs with, lavas of a rhyolitic composition.

These considerations, which may be equally applied to the order of succession of massive eruptions and to that of volcanic lavas, are not given with a view of explain-

ing this intricate subject, but only to show that natural occurrences may, with the aid of the theory here advocated, be explained without having recourse to any forced assumptions. There is no one of the processes pointed out which is not within the limits of those we are accustomed to consider as highly probable in regard to that part of volcanic action which is removed only a little way beyond immediate observation, and therefore more accessible to well-founded speculation than is the remoter connection between volcanic action and the fissures through which the massive eruptions of volcanic rocks took place.

3. *Other Theories respecting the Origin of Eruptive Rocks.*

The various theories which have been proposed in regard to the origin, not only of the volcanic but of all those non-foliated crystalline rocks which are made up of silicates, diverge in different directions. Most of them, however, leave unnoticed the most essential features of those rocks, such as their nature in regard to the details of chemical composition, their similarity in character in distant countries and different ages, the laws of their mode of succession and distribution, and the fact of their periodical emission after long periods of repose ; and no one undertakes to account for all of them. There may be distinguished two classes of these theories : the first comprehends those which assume the original seat of eruptive rocks to have been beneath the sedimentary rocks, while the second embraces those which would have it to be within the shell composed of the latter. It was the purpose of our foregoing theoretical considerations to point out, that it is exclusively in the direction followed by the theories of the first class that we may at all look for a satisfactory explanation of the relations presented by the eruptive rocks. But, though the views here advocated belong altogether to this class, the leading theories embraced in it have a very different scope. That form of them which was held by Buch, Humboldt and others of the most prominent geologists, and is still quite largely adopted, starts from the assumption that all eruptive rocks were ejected in the same condition in which they are supposed to have been when at their original place in the earth's interior, that is, molten by dry heat ; while the contraction of the globe by loss of heat is regarded as the sole cause of their ejection. Among the weighty objections which may be raised against these theories, may be mentioned : that the eruptive rocks on their arrival at the surface have evidently not had a temperature which would be sufficient for their dry melting ; that they contain a certain proportion of water enclosed, which was formerly not brought into account ; that the ejection from the depth to the surface of masses molten by dry heat is a process impossible of explanation, and that, if it was possible, the rocks should have a different texture from that exhibited by granite, diorite or propylite ; that, finally, contraction alone is as little capable of furnishing an agent for the rending of fissures opening towards the surface, which is the prime condition of eruptive activity, as is the cooling of the globe of giving the conditions requisite for the process of ejection itself. The theories mentioned have been longest maintained on the European continent, where they are even now advocated by many. Though approaching nearest of all to the most probable mode of origin of eruptive rocks, the reasons

why they are untenable, with our present state of knowledge, are too obvious to be made an object of a more detailed explanation.

More numerous and more obvious objections may be raised, chiefly from a geological point of view, against those theories of the second class, according to which all the rocks under consideration, with the exception of those lavas which we actually see being ejected from volcanoes, would have derived their origin exclusively from metamorphism *in situ;* be it that the change is supposed to have been mainly of a chemical nature, and effected on or beneath the surface, by the action of water alone containing certain substances in solution, or that refuge be taken to the coöperation of superheated water and pressure at a great depth. A large amount of positive facts as well as of sagacious reasoning have been applied in their defense; but viewed in the light of those observations which present themselves continually to the geologist in the field, in evidence of an essentially intrusive and extrusive nature of those rocks, the premises on which argumentation is based must appear extremely deficient. Also will the reasons which we shall adduce against the leading theory of our day, be applicable *a fortiori* against the assumption of an origin of our "eruptive" rocks only by metamorphism *in situ*. Before entering upon that leading theory, we have still to mention the existence of a number of others, which, though acknowledging the probability of an origin of all lava and "trap-rocks" from the liquid interior of the globe, assume that granite, syenite, diabase, diorite and certain porphyries are so-called hypogene rocks, that is, have originated by metamorphism of sediments *in situ*. Against these theories may be raised the collective objections which apply severally to the others.

The obvious objections which may be made to the theories hitherto mentioned have given more and more ascendency to another doctrine, which we may designate as the metamorphic theory of eruptive rocks, and which owes its great influence upon modern geology to the fact of its starting from a certain number of established geological facts and lithological observations, and from the results of experiments. It is eminently a theory of the second class. No arguments against it will be more potent than those which prove the fallacy of the basis of all the theories of this class, as they will show that we must look for the origin of eruptive rocks altogether in a different direction from that followed by them.

The metamorphic theory is essentially to the purport, that all eruptive rocks, whether of recent or of ancient age, whether ejected by volcanic action or carried into their present position without any sign of the latter, were originally sedimentary rocks rendered liquid by the coöperation of heat, pressure, and water. It is supposed that these rocks, by the continued superposition of immense masses of sediment, had arrived at a great depth under the surface, where the agencies mentioned would coöperate to modify and transform their state of aggregation, resulting either in a molecular change alone, or in their conduction into a state of fusion. In the former case, the sediments would be simply metamorphosed, while in the latter, they would either crystallize in depth, with a total loss of their original structure, and form "plutonic," or "hypogene," or "indigenous" rocks, or be forced upwards through fractures, and solidify partly in the conducting channels and partly on the surface, when they would

form "trap rocks" and "lava." One common cause is thus assigned to both metamorphic and eruptive (including volcanic) action, the latter being considered an advanced stage and ultimate result of the former. The immense action of metamorphism is an undeniable fact. But while formerly, on account of the violent agencies which were supposed to have been required for it, and the growing conviction that heat alone could not produce effects on such an enormous scale as had been suggested, the subject had to be treated with caution, and any extreme assumption was received with doubt, if not with a certain repulsion, the condition of things, in this respect, has of late undergone a great change, as scientific experiments, and especially those of Daubrée, have demonstrated the extent of the influence of water and pressure in producing metamorphic action. They have proved the remarkable fact that, at a comparatively low temperature, and with the aid of pressure, the effects of water, if continued for a sufficient time, particularly when it is charged with alkaline substances, will be able to produce changes in the nature of rocks which surpass even the most audacious assumptions of former time. An apparently safe foundation was now given to the widest generalizations, and the consequence is, that an almost unlimited action is at the present time brought to the account of metamorphism.[23] The least founded conception, however, of the faculties ascribed to it, we consider to be its supposed sole instrumentality in the production of volcanoes and the eruptive action of former ages from portions of the shell of sedimentary rocks. It is true that a great additional degree of apparent probability has been given to the metamorphic theory of eruptive rocks by the results of the microscopic examination of rocks so successfully instituted by Sorby, since they prove a remarkable similarity, in the minutest texture, of the minerals constituting granite and some cognate non-foliated rocks, with the main ingredients of certain foliated rocks made up of silicates, such as gneiss and micaschist. These had been observed long before to form the last link of a series which may be traced, by slow gradations, from unmetamorphosed sedimentary rocks, through those which are undoubtedly metamorphosed, up to the crystalline foliated rocks mentioned. The newly discovered facts appeared to indicate that granitic texture is the most advanced stage in a progressive series of molecular changes, and, carrying the argumentation still farther, the assumption was apparently justified that a corresponding origin must be ascribed to other rocks, such as those of volcanic origin, which are connected with granite by another long and gradual line of passage.

In drawing up our argument against this theory, (including all those doctrines

[23] It may be frequently noticed, that those eminent men who, by creating a firm basis for induction, have pointed out the path through regions in the field of science the knowledge of which had consisted before of a confused accumulation of facts and suggestions, did themselves apply the newly acquired views within moderate limits, while sweeping generalizations on the same basis were usually made by others. It is so in the present case. The limits within which Daubrée himself has applied his ingenious conclusions from his experiments on the action of superheated water and pressure upon silicates, will probably never be drawn any closer. No discovery, however, could have been more opportune to those who had advocated before the origin of eruptive by the remelting of sedimentary rocks. Against the form of this theory which was first proposed by Hutton, and enlarged by Lyell, Babbage, Herschel and others, similar objections could be raised as against that form of the theories of the first class which was held by Buch. With the aid of the new views acquired, however, it was remodeled and brought into its present shape. A far greater extent is thus being given to the conclusions from Mr. Daubrée's experiments than their author ever intended.

which assume either all or a part of the massive crystalline rocks composed of silicates to have originated by the metamorphism of sediments) we will first point out some reasons against its general tenor, which may be conclusive in regard to those rocks the eruptive nature of which is almost generally conceded, while we will have to bring some additional arguments against its special application to those which are often designated as "hypogene" or "plutonic."

The metamorphic theory starts from the assumption of an alternating progression from the center of the earth, and recession towards it, of the chthonisothermal planes, the former being caused by sedimentary deposition, the latter by denudation.[24] It is then argued that, by the progression of these planes, sedimentary strata would acquire a more and more elevated temperature, and, being permeated by water, would be metamorphosed, and finally rendered liquid. It is demonstrated that heat, generated by the plication of the strata in the lowest and central part of an area of subsidence, would aid in promoting these changes, which would end in the rupturing of the crust and the protrusion of liquid matter. Eruptive activity should, according to these views, be confined to areas of subsidence, in particular to their central portions. Geological observation does not favor this conclusion, since the emission, at least of the volcanic rocks, has taken place on the borders of those areas, on high table lands, and, in general, in places which have undergone elevation before and since the time of the first commencement of the eruptive activity.

It would appear that the experiments of Daubrée should not be too freely applied to reasoning on processes within the shell of sedimentary rocks. They have been made with relatively large quantities of water, such as can scarcely be expected to be present in solid rock at some distance below the ground. Supposing that that quantity naturally enclosed in it would, under great pressure, cause its fusion, then no reason can be adduced why there should not prevail a liquid state of all matter at a limited depth below the surface, and over extensive regions, if not over the whole globe. That such is not the case, is evident from the want of any signs of subterranean tides. Leaving this difficulty out of consideration, another presents itself concerning the periodicity of eruptive activity. If processes such as those suggested by the adherents of the metamorphic doctrine were its cause, then it would be impossible to give an explanation, why there have been long eras of rest intervening between others of violent eruptive activity, or why the latter was of general distribution over the globe during the Tertiary era, and preceded by a period of rest which was probably no less general. The phenomena of vulcanism might have manifested themselves at a certain time more in one country than in another, if metamorphism had been their cause, since their principal theater would be constantly shifted to the places of the most violent metamorphic action; yet they should, at least in the aggregate, have been continuous.

These objections, however, against the metamorphic theory of eruptive rocks are of little weight when compared with another, respecting their nature as chemical

[24] It is needless to enter here upon a discussion of the causes and effects attributed to these phases in the "flow of heat" by the adherents of the metamorphic theory, since this topic has been made lately the subject of a paper by the skillful hand of Professor Dana.

compounds. It is from this point of view, as we have repeatedly remarked, that are offered the chief and most deeply-founded differences between the eruptive and the stratified and foliated rocks. Definite numerical relations on the one side, complete absence of them on the other, and a transition between both, marked by the gradual disappearance of those relations with the passage from granite, in which they are very distinct, to gneiss and micaschist—these are in short the prominent characters of the great divisions of those rocks which are accessible to the observations of the geologist. We alluded at another place to the corollary of this distinction, namely: that it is impossible that eruptive rocks are remelted sediments, because, if they were, they would necessarily have to participate in the varied and indefinite chemical composition of these. This important argument appears to have been completely overlooked by the adherents of the metamorphic doctrine, and it would be sufficient by itself to make the latter appear to be in contradiction with the true state of facts.[25]

If we descend from this general tie embracing the totality of eruptive rocks, to those relations which either separate or connect distinct groups of them, in regard to the time at which they came to the surface, we are unable to find any explanation of the peculiar uniformity of these relations, if we adopt the metamorphic doctrine. Rocks of great mutual similarity might have been occasionally ejected at different places; but the repetition of the same order of succession in distant regions would be just as inexplicable, and contradictory to the nature of sedimentary rocks, as the perfect chemical identity of rocks which are widely separated in space, but occupy a similar position in the order of succession.

Another geological consideration may be mentioned which appears to weaken the metamorphic theory. It is known that the most ancient rocks are distinguished, in general, by a much greater similarity among each other in respect to chemical composition than is the case with those of more recent origin, and that one prominent feature of the majority of them is the presence of silica in a similar proportion to that in which it is contained in granite. The formation of sedimentary rocks having been due, at all times, to the disintegration of rocky matter antecedent to them in age, it is obvious that ancient sediments would have participated in the silicious nature of the

[25] It can hardly be comprehended that it should have been maintained, and be believed, with our present state of knowledge, that clayslates were, by metamorphic action, converted into granite and syenite, and sandstones into porphyry; since granite and (quartzose) porphyry are chemically identical, while clayslate and sandstone differ in this respect not only among themselves, but each of them represents a large number of different accidental compounds, without any law of mutual connection. The supposition that "the presence of the sandstone formations affords the conditions required for the occurrence of the great porphyry-masses," gives evidence of an interpretation of natural occurrences by preconceived ideas. There are, it is true, numerous instances of sandstones having acquired, by metamorphic action, a more or less perfect porphyritic texture, so as to be hardly capable of being distinguished, in specimens, from true eruptive porphyries; but geological observation will seldom leave any doubt in regard to their true mode of occurrence; and, as a generality, it is not difficult to distinguish these metamorphic rocks with porphyritic texture from "the great porphyry-masses," such as those of southern Norway, or middle Germany, to which the above-mentioned supposition has been especially applied. It is evident that the eruptions of the porphyritic rocks were there subaqueous, and that the true relation is exactly the reverse of that suggested: the ejection of great masses of quartzose porphyry afforded all the conditions required for the formation of sandstone beds. Quartzose porphyry did overflow vast regions, and, by its immediate disintegration into tufaceous matter, gave origin to those red sandstones by which it is so often accompanied. These cover the porphyry often in horizontal beds, and bear to it similar relations of gradual passage and interstratification, as trachytic tufa does to trachyte, where the eruptions of the latter were subaqueous.

rocks by the destruction of which they originated, and should have had a tendency towards an average between them in regard to chemical composition. If such sediments were afterwards rendered liquid by metamorphic processes, and either carried to the surface as eruptive rocks, or solidified beneath it, so as to form part of it only after ages of denudation—if they were then again partially disintegrated, re-deposited and reërupted, and so forth, down to our time, the final result should be an ever-increasing uniformity in composition of both eruptive matter and sediments. It may be objected, that this tendency towards uniformity must have been checked by the formation of chemical sediments, as by them a portion of certain elements was eliminated, and must have become almost irrecoverably lost for further participation in the supposed revolving process. The substances prevailing in chemical deposits are lime, soda and magnesia. Recent eruptive rocks should, therefore, besides showing a uniformity of composition, be somewhat deficient in those substances, and contain in proportion more of silica, alumina and potassa. The facts are exactly reverse. Not alone has the variety of eruptive rocks rather been constantly increasing; but, among those most recent in origin, such are greatly predominant as contain lime, soda and magnesia in larger proportion than ancient rocks, while they are relatively deficient in silica, alumina and potassa. We arrive by this last line of argument at the conclusion, in the first place, that the present variety of rocks, especially of those of eruptive origin, can in no way be explained by, but is contradictory to, the assumption that they originated by the repeated destruction and reformation of the material which constituted the surface of the globe in the most ancient time. From this it follows, in the second place, that, even supposing that the theory should be admissible for the majority of eruptive rocks, entirely new matter must have come repeatedly to the surface, in order to replace the constant loss, as it were, of substances such as lime and soda. Eruptive rocks ascending from sources beneath the deepest sediments are the only means imaginable for the performance of this function. The enormous extent to which matter must have been supplied from that source is especially evident, if it is considered that there must have been a time when no sediments existed on the face of the globe, and that the disintegration of preëxisting matter is the prime condition to their formation. The entire mass of the sediments which make up the exterior shell must, therefore, have been derived from the destruction, partly of the original crust which solidified on the globe, and partly of those rocky masses which protruded through that crust to the surface. It is eminently probable that the mass of matter derived from the latter source exceeds very far that which is due to the first. This consideration shows that it is hardly possible for us to form an adequate idea of the vast importance which the periodical emission of rocky matter from places beneath the primordial surface must have had in the history of the formation of the crust of the globe.

We may thus start from any point of view within the range of positive knowledge, and we shall find that there is not one line of argumentation which does not go to show that the doctrine of the origin of eruptive rocks by the metamorphism of sedimentary matter is irreconcilable with the most prominent established facts. Not only does it fail completely to explain them, but with most of them it is in obvious contradiction. But as a metamorphic origin has been proved to evidence in regard to

certain foliated rocks, and as it appears no less safe to conclude that those rocks, the intrusive or extrusive character of which is generally admitted, originated from below the sedimentary rocks, we have still to examine where is the limit to which the theory of such an origin may be safely applied. A line of gradual passages connects the foliated rocks with gneiss, and through it with granite, and another line of gradual passages can be traced from the volcanic through the porphyritic to the granitic, and through them again to the gneissoid rocks. The affinity of granite and gneiss may therefore be said to be the central point from which all other lines of passage in the nature of rocks diverge; and it must be ascribed to this relation, that many geologists, while admitting the origin from below the crust of the globe of "trap-rocks" and "lava," still consider granite, syenite and cognate rocks to have been generated by the metamorphism of sediments, and to occupy now the same position which these sediments had before being metamorphosed. The peculiar character of granitic texture, which is nearer allied to that of foliated crystalline than to that of volcanic rocks, the geological occurrence of granite in intimate connection with those and its apparent independence of position in reference to the latter, the singular order of solidification of the minerals constituting granitic rocks—these and other reasons of a similar kind would indeed appear to support the assumption that granitic and volcanic rocks differ in regard to their origin; while, on the other hand, additional probability is apparently given to the connection of granite and foliated rocks in regard to their mode of origin, if it is taken into consideration that many varieties of gneiss resemble granite closely in chemical composition, although others deviate from it in this respect and do not conform to the law of Bunsen.

According to the theory here advocated, all those rocks will be the true representatives of the primordial mass of the globe, which are subject, in regard to their composition, to the law of Bunsen, and occur, besides, in positions which place beyond doubt their intrusive or extrusive origin, so far as they no longer occupy their original place. As regards the first distinguishing mark, it is known that granite, syenite, diorite, diabase, and nearly all those porphyritic rocks which have been considered as of hypogene origin are subject to the law of Bunsen, as far as their composition has been ascertained. In this respect, therefore, they are fundamentally different from sedimentary and metamorphic rocks. Although believing this to be conclusive evidence of their origin from below the shell of sediments, we must enter into a short discussion of the chief objections which have been raised against the necessary corollary from this mode of origin, which is the eruptive character of those portions of granite which we see on the surface, and the assumption of the existence of this as the foundation of all sedimentary rocks.

It is argued by the adherents of the metamorphic theory of eruptive rocks, in the first place, that granite cannot be the fundamental rock in the crust of the globe, on which those of sedimentary origin are resting, since even very ancient masses of it are frequently found to overlie stratified rocks. But this fact, which was known long ago, shows only that it is impossible, on account of the great thickness of sedimentary rocks, to know by ocular observation of what nature is the fundamental rock. It is

logically absurd to assume the non-existence of a foundation consisting of rocks differing in origin from sedimentary rocks; and the conclusion is inevitable, that it must be composed of rocks which were generated by the solidification of such masses as formed part of the primordial substance of the globe, next to the surface. Probabilities accumulate to point towards the assumption that very silicious granite composes that foundation, together with such gneissoid rocks as must be supposed to have been formed in an incipient sea of very high temperature, and under the pressure of the superincumbent atmosphere of aqueous vapors, at a time when the cooling of the globe had advanced far enough to allow of their first condensation, and when pressure, water, and heat could coöperate to produce on its surface similar effects to those which the same agencies are supposed to have wrought in later periods at an ever-growing distance from it. The most probable mode of these ancient processes has been pointed out by Daubrée. The true nature of the foundation rock can, of course, not be positively known, but must remain a matter of conjecture. No solution of this problem will, however, be more satisfactory than that which is based on the hypothesis of Sartorius, because it is in harmony with all the phenomena of vulcanism. The probabilities in favor of a granitic foundation are, therefore, very great, while no valid objection has yet been raised against its having the nature indicated.

It is further argued that, the position of granite being always in the midst of sedimentary, or of such foliated crystalline rocks as are connected with the former by gradual passage, and often conspicuously above such rocks, the only material from which it could be generated are the sedimentary rocks themselves. The arguments brought in evidence of these assertions are among the most potent which can be adduced against them. Granite, in Norway, is superposed on Laurentian rocks turned upon their edges, and, as no channel can be found by which it ascended, it is argued that it must have been generated by metamorphism *in situ*. But as, on the other hand, it has justly been remarked, that no position is more favorable for metamorphic action than that of upturned strata, it is difficult to comprehend why the Laurentian rocks, which were evidently nearer to the source of heat, should not have been metamorphosed in a much higher degree than the overlying granite. The same objection may be made in other instances, as in the case of the Huronian and Laurentian rocks in Canada, which were found to be overlain by granite thousands of feet in thickness. The negative evidence, apparently afforded by the fact that no channels have been discovered through which the granite could have protruded, is of very slight value, if it is taken into consideration how rare are the instances where the conducting channels can be seen, in the case of overflows of volcanic rocks, or even in that of currents of lava. There are a few more instances known where granite can be distinctly observed to overlie the upturned edges of stratified rocks, and must, therefore, have overflowed the same in a liquid state. In some other cases, as in those of the extensive granitic areas of Bessarabia and Western Australia, the true geological position of granite escapes observation; while, in a number of others, it has the appearance of an intrusive mass.

The strongest objection which may be made to the eruptive nature of granite relates to its lithological characters, which are different from those of the

eruptive rocks of the present era. The metamorphic theory suggests that enormous volumes of those masses which it supposes to have been rendered liquid by metamorphism, and small portions of which were occasionally emitted to the surface, did solidify below ground with a total loss of their previous structure, and may arrive at the surface by elevation and denudation. Granite is supposed to have been in all cases a hypogene rock, generated by metamorphism in those same positions in which it is found at the present time, and to be still formed continually in the same way; though it is admitted that the tension which may have attended its former state of liquidity, may have caused it to ramify into rents and fissures of the overlying rocks. We have, of course, to assume the existence of an immensely greater amount of hypogene matter corresponding in composition to all the different eruptive rocks, but buried so deep beneath the present surface, that, possibly with the exception of a few granite masses, it never does, nor ever will, form part of it. We have, for this reason, to consider all non-foliated crystalline rocks made up of silicates, and which are visible on the surface, as having been removed far from their original seat, and therefore as being eruptive. It is a matter of course that only a very small portion of all matter protruded from the depth would be ejected to the surface, as by far the greater portion would solidify within the channels of ejection. Granite occupies frequently the latter position quite distinctly. But if we consider those large accumulations of the same rock covering hundreds of square miles, we can only explain them in two ways. Either they must occupy their primeval position, as is supposed by the adherents of the metamorphic doctrine, or they must have been ejected and spread in a liquid state over the underlying rocks. The objections against the first supposition are, the adaptation of granite to the law of Bunsen, and the fact already noticed, that it overlies the upturned edges of strata; the objection against the other is the peculiar mineral character of granite. But we should always bear in mind that our knowledge in regard to the conditions required for producing any certain kind of mineral character within a compound of silicates of any certain composition is very limited, as is illustrated, among others, in the cases of propylite or dolerite; and the inferences based on subjects which are imperfectly known to us should, in geology, always be made subordinate to those which we can positively establish by observations. It is not on the ground of the latter that a hypogene origin is ascribed to all granite, but on the ground of its mineral characters. It is said that granitic and volcanic rocks offer quite generally a different appearance, and that the texture of the former indicates crystallization under great pressure, while the volcanic rocks were evidently solidified on the surface. As regards the first assertion, such rocks only should be compared together as have a similar composition, that is, granite with rhyolite, or diabase and augitic porphyry with basalt; not, as is ordinarily done, granite with phonolite or basalt. We referred already to the similarity in character between certain varieties of rhyolite and granite. It is corroborated by the microscopic examination of these rocks by Ferd. Zirkel, from whose memoir[26] I quote the following passages: "Quartziferous trachytic

[26] Dr. Ferdinand Zirkel, Mikroskopische Gesteinsstudien, in *Sitzungsberichte der Kais. Acad. der Wissenschaften zu Wien, vol.* 47, 1863.

porphyry (rhyolite) cannot be distinguished under the microscope in any respect whatever from felsitic porphyry. If one dare not doubt the eruptive origin of the former, one cannot but acknowledge the same mode of origin in regard to the latter." And again: "Let us here remark, that the microscopic structure (texture) of trachytic quartz does not differ in any respect from that of granitic quartz; there is no difference between these two families of rocks so widely separated in time, either as regards the number or the appearance of the water and glass cavities." Considering the second of the before-mentioned assertions, it is true that Mr. Sorby has, by his sagacious observations, come to the conclusion that granite solidified at a temperature of about 600° Fahr., and that the various granites have been formed under a pressure equivalent to a depth of from 40,000 to 69,000 feet. The calculation by which these figures were obtained, is made upon the basis of the proportion between the bulk of the water contained in the microscopic cavities, and the size of the vacuity, the latter being supposed to indicate that the water had formerly filled the entire cavity and contracted within it after the solidification of the surrounding rock. The laws of hydrostatic pressure, however, as Daubrée justly remarks, are in such a case not applicable in the same way as they would be in a column of water ascending through a fissure; temperature and pressure may, in a mass of rock solidifying from a viscous state, be preserved, as in a closed vessel, to within a few feet from the surface; "it is, therefore, possible that many processes, such as the crystallization of granite, may have been going on under pressure, though at a very limited depth." Considering that a mass of granite, after the solidification of its exterior portion, will indeed be enclosed within walls that may offer a strong resistance equivalent to a great pressure, it may be inferred that it will assume, in crystallizing, a similar texture to that which it would have obtained if the same process had been going on at a great depth below the surface. It can hardly be suggested what must have been the texture of the crust of a granitic mass. But the age of the granite is sufficient to justify the conclusion that the crust of those masses which solidified on the surface of the globe must have been completely abraded, and only those portions be preserved to observation which consolidated under considerable pressure.

Though these arguments may show that the difference in the character of a large mass of rock need not necessarily be proportionate to the depth under the surface of the globe at which it solidified, and that granitic and volcanic rocks are nearly related as regards their microscopic texture; yet, the conspicuous external differences between these two classes of rocks must remain a problem difficult of solution. The proportionate rapidity with which volcanic rocks, on account of their usually small volume, must have cooled, may be among the reasons. But it is not the only one. There are differences in the nature of rocks, which escape our present means of explanation. Hornblende-propylite, though no doubt at all can be entertained in regard to its subaërial solidification, has completely the character of the so-called Plutonic rocks, and yet lacks their supposed principal distinguishing mark: crystallization in depth. Considering that certain varieties of propylite, andesite, and trachyte are modifications of the same group of chemical compounds; and, though having been solidified on the surface of the globe within a short period, yet exhibit marked external differences, we can-

not be surprised to see, that other rocks composed of silicates, which are so widely separated in time as is the case with granite and rhyolite, should offer even greater differences. Some further clue to a better knowledge of this subject may be expected from the study of the nature of volcanic rocks. We see the same chemical compound forming highly viscid lava in one volcanic crater, while it is quite liquid in another. There, it solidifies to dolerite or leucitophyre; here, to basalt. Similar influences appear to work greater differences in more silicious compounds. We should therefore put little value on the doubts entertained in regard to the solidification of granite, as of a rock ejected on the surface and expanded over it, until we are better acquainted with the causes of the lithological differences among volcanic rocks; and the evidence regarding the mode of origin of granite should, till then, be mainly taken from its geological occurrence and its chemical composition.

Relation of the Distribution of the Volcanic Rocks to the Configuration of the Surface of the Globe.

If we embrace in a broad review all those relations mentioned in the foregoing chapters which regard the history of eruptive action, we arrive at the general conclusion that, in reference to the entire globe, it is one homogeneous and harmonious whole, and has been attended by such gradual changes only as were necessarily occasioned by the progress of the physical development of the globe itself, while, in regard to every different part, it presents a series of distinct phases intimately connected by mutual relations. It would be a subject worthy of the closest investigation, to trace the effect which the events of these phases have had severally upon the structure and the configuration of any separate country. A comparison of these effects as they are manifested in different regions would then aid in establishing some of the chief causes of the differences of structure peculiar to each; and the knowledge of these would make us better acquainted with the laws governing the evolution of the globe, and prepare the way for a more thorough understanding of its physical geography. I will only attempt at this place to trace the effects referred to in regard to the last of the phases of eruptive activity, the only one which was nearly contemporaneous in all countries. It occurred at a comparatively recent date, and we can view the results in a clearer light than we can those which are remote in time and partly obliterated by the vast changes which since then have revolutionized the surface.

We have, in the first place, to trace more in detail than we have done before, the peculiarities of the distribution of volcanic rocks. It has been observed that active volcanoes are chiefly situated along the lines of the present sea-coasts, especially at the foot of mountain ranges parallel to them; or that they follow elevated submarine ranges, when they will either remain submerged beneath the sea, or protrude above it, forming chains of islands. Some of these appear to mark the lines of high mountain ranges bounding submarine continents, if we may use this expression for those areas of a shallow sea-bottom which are separated from others of great depth by wall-like elevations, as are indicated for instance in the main ranges of the vol-

canoes of the Indian Archipelago. Active volcanoes have also been found to be particularly numerous in those regions where the narrow terminations of two continents verge towards connection, as is the case in Central America, between Alaska and Kamtschatka, and between Australia and Farther India. The mode of distribution of extinct volcanoes has been little investigated. But as they are far more numerous than active vents, and as volcanic action has completely ceased in extensive regions, a perfect understanding of the distribution of volcanic activity on the globe can only be acquired when they shall be fully taken into consideration. The general laws of their distribution appear not to differ from those relating to active volcanoes. They, too, have been evidently dependent upon the course of the sea-coasts which existed at the time of their activity, and were in many places quite different from those of the present epoch. But we must note, besides, this additional feature of extinct volcanoes, that among the theaters of their grandest and most extensive displays are certain countries which were formerly covered with large inland basins filled with salt water, and form now mostly elevated table-lands on which may still be seen the remnants of those former inland seas. Volcanoes so situated form often crowded groups occurring at distances of more than five hundred miles from the sea-coasts which existed contemporaneously with their activity. To them belong the numerous extinct volcanoes on the plateau between the Sierra Nevada and the Rocky Mountains, a region which has probably had no equal in regard to the extent in which volcanic activity has taken place, as it comprises the States and Territories of Oregon, Idaho, Montana, Utah, Colorado, Nevada, California, Arizona, New Mexico, and continues southerly to the high lands of Mexico. Other volcanoes of high table-lands are those of the Mongolian Desert, the Thian-Shan, Armenia and, probably, eastern Africa. The volcanoes of all these regions are extinct, with the exception of a few in the southern part of the plateau of Mexico, which are in action, and some others which still exhibit solfataric phenomena.

Interesting as would be a map embracing all active and extinct volcanoes, it would give only the outlines of the distribution of those larger accumulations of volcanic rocks which were produced by massive eruptions, and have ordinarily attracted little attention.[27] Geological maps being often imperfect as regards them, it is not yet possible to distinguish any other features of their distribution than those mentioned in reference to volcanoes, as they can always be found in the vicinity of these. We may however add, that massive accumulations may eventually be found near the summits of mountain ranges, where volcanoes do ordinarily not occur.

[27] This may be exemplified in regard to the Andes of North and South America. Humboldt (Cosmos, vol. iv) distinguishes five groups of volcanoes, separated by non-volcanic regions. They are mentioned by him as follows: 1st, volcanic group of Mexico, nearly five hundred miles in length, but occupying scarcely more than one degree of latitude, on account of its direction from east to west; 2d, three hundred and fifty miles free from volcanoes; 3d, group of Central America, having a length of over eight hundred miles; 4th, seven hundred and thirty-five miles non-volcanic; 5th, group of New Granada and Quito, five hundred and fifty-five miles in extent; 6th, the longest interval without volcanoes, being 1,133 miles; 7th, group of volcanoes of Peru and Bolivia, extending over five hundred miles; 8th, a non-volcanic space of six hundred and twenty miles 9th, the group of Chile, the most extensive range of volcanoes of America, being 1,143 miles in length. Summing up, Humboldt takes about 3,000 miles to be the aggregate extent in length of the volcanic regions, 2,838 miles that of the intermediate spaces which are free from volcanoes. If all the volcanic rocks occurring in the Andes

If we turn our attention from the mode of the geographical to that of the geological occurrence of volcanic rocks, we may first consider from this point of view the relations just mentioned. The two modes of distribution which are most conspicuous, namely, on the foot of mountain ranges and along sea-coasts, are nearly identical in a geological aspect. For most, if not all of those ranges the flanks or vicinity of which are distinguished by the occurrence of volcanic rocks on a large scale, have been contiguous to sea-coasts in the Tertiary period, or they are so at present, or they have been so in the intermediate time. This is true of active and extinct volcanoes, as well as for massive eruptions, in the Carpathians, on the southern foot of the Alps, on the borders of the plains of northern Germany, on the slopes of the central plateau of Asia, in their whole extent from Armenia and the Caucasus, passing Lake Issikul and Lake Baikal, to the vicinity of Pekin, in the coast ranges of California, in the Cascade Mountains of Oregon, and in numerous other countries. As regards the prominent occurrence of volcanic rocks on high table-lands, it is analogous to their situation on sea-coasts, inasmuch as the salt lakes occurring on them, which were of much larger size in the Tertiary period, would be an equivalent of the vicinity of the sea. Those larger regions not covered by salt lakes, which are situated in the interior of continents, and have been so since the commencement of the Tertiary period, were generally not the theater of outbreaks of volcanic rocks. This circumstance renders almost certain the influence which the neighborhood of large quantities of salt water has had upon the commencement and main phases of the eruptive activity, though its continuation in the latter phases, which are those of volcanic action proper, may in numerous instances have been maintained by fresh water.

The relations of the distribution of the volcanic to that of the granitic and porphyritic rocks have been considered in another chapter. There is probably no place distinguished by the accumulation of the first where the previous eruption either of granitic or of both granitic and porphyritic rocks may not be observed, if the conditions are such that observations in this direction are possible. But as there are porphyritic regions outside of the volcanic belts (for instance, the quartzose porphyries of southern Norway, or the Triassic trap-rocks of the Connecticut Valley), and as the same is true of a great number of known granitic districts, and probably of a far greater number of others which are not accessible to observation, it is evident that the existence of ancient channels of ejection did not necessarily imply their reopening in the Tertiary period, while there can scarcely be any doubt that the once shattered places where they were situated offered less resistance to the formation of new fractures, than other portions of those regions in which the greatest disturbances took place in the Tertiary period.

We have, finally, to mention the connection which apparently exists between the occurrence of volcanic rocks and the regions where ancient formations have been

---

were laid down on a map, it would hardly show such great intermissions. The extensive fields of lava found by Capt. Fitzroy, in southern Patagonia, the volcanic rocks of the Desert of Atacama, and of northern Peru, are instances of their extensive distribution in the non-volcanic spaces of South America, while on the northern continent they are one of the main features in the structure of the great western mountain ranges, probably throughout their whole extent from Panama to the peninsula of Alaska, and are accompanied probably by thousands of extinct craters.

highly disturbed and subjected to an extensive metamorphism. It appears that the eruptive action was in a great measure, perhaps absolutely, limited to regions which offered this condition. But this connection by no means justifies the conclusion that the existence of metamorphic foliated rocks was among the first causes of the ejection of volcanic rocks. There are not only countries, such as the mountains of Scandinavia, the Ural Mountains, the Appalachians, and other ranges distinguished by the records of a very ancient metamorphism, where no trace of volcanoes has been found; but this applies even to a few, though particularly grand instances of mountain ranges which were the theater of metamorphic action on a grand scale within the most recent periods, such as the Alps, the Himalaya, and the Pyrenees.

The two last named relations, both conspicuous, yet both secondary in importance, are evidently nearly identical, since granite enters, probably in all cases, into the structure of those same countries which have been the theater of an extensive metamorphic action. It is, however, worthy of note that, of the regions so distinguished, part of those only appear to have become the theater of eruptive activity in the Tertiary period, where granite must, by the mode of its occurrence, be assumed to have formerly been extruded to the surface, as is the case in the Sierra Nevada, on the southern foot of the Alps, in middle Germany, and in central France, while no volcanic rocks arrived at the surface in other mountain ranges where granite occurs only in the shape of wedges surrounded by foliated rocks, and bears a merely intrusive character, as in the central range of the Alps.[28]

[28] Another peculiarity in the distribution of volcanic rocks may be noticed. It is their outbreak at places of dislocation or faulting of mountain ranges, if we may apply these expressions for the immense displacements which some of the latter have undergone, along lines either at angles with or parallel to their direction. A remarkable instance of the first kind is afforded in Hungary, where a fracture, along the line Eperies-Kaschau, crosses the Carpathians in a nearly meridional direction. To the west of it, ancient formations, along with granitic, porphyritic, and volcanic rocks, make up the surface, and are elevated to high mountain ranges culminating in the High Tatra. They extend eastward close to the fracture, and there terminate abruptly. East of it, the main chain of the Carpathians continues as a range of little elevation, and consisting chiefly of Cretaceous and Eocene rocks, while the high foothills of the western part are replaced by the Hungarian plains. Immediately out of the fracture rises the Eperies-Kaschau range, of nearly one hundred miles in length, which consists exclusively of volcanic rocks. The subsidence of the land on the eastern side of the fracture must have amounted to several thousand feet in this case. A transverse dislocation of similar magnitude, by which the western side was sunk thousands of feet, is observable on the eastern bank of the Rhine, along the boundary of Switzerland and Vorarlberg. No volcanic rocks however are visible at that place, which fact appears to be in accordance with the absence of any ancient eruptive rocks in the neighborhood, and the wedge-like shape of granite in the nearest places of its occurrence. A peculiar instance is afforded by the three porphyritic regions on the southern slope of the Alps, each of which indicates a deep depression, bounded by longitudinal and transverse fractures, of that area which has in each case been the seat of eruptive action. Prof. J. D. Whitney and I had occasion to observe another instance, more forcibly striking for its grandeur than any of the foregoing. Following the crest of the unbroken range of the Sierra Nevada, from south-southeast to north-northwest, one arrives in the northern part of the County of Plumas at a sudden change of scenery and rocks. The metamorphic rocks of the Sierra Nevada are broken off and terminate in a line apparently at about right angles with the direction of the crest of the former. The rugged and wild scenery which they present, particularly in this county, gives way abruptly to one equally remarkable for its beauty and geological interest. The high volcano, Lassen's Peak, rises in the distance, amidst an intensely volcanic group of hills. Low forest-clad ridges built of lava, and separated by meandering plains covered by meadows, stretch southward from it, gradually sloping down towards the line of dislocation, and there abut against the wall of metamorphic rocks. The whole surface, though lower than the summit range, is entirely volcanic. Seventy miles northwest from Lassen's Peak rises Mount Shasta, more sublime even than the other. Between both is a deep depression, through which the Pit River takes its course from northeast to southwest, at little altitude above the sea. This depression is situated at the very place where the crest of the Sierra Nevada should pass, and is directed transversely to it. Northwest of Mount Shasta, Prof. W. H. Brewer found the continuation of the Sierra Nevada, with similar char-

These appear to be the most essential geographical and geological relations regarding the mode of distribution and occurrence of volcanic rocks. It is perfectly evident that no one of them singly was the chief cause of their occurrence, nor were all of them together; but each of them had a marked influence, either upon the direction and the location of the orifices of the fractures, or upon the mode of ejection. Keeping in view these different relations, I shall dwell, in the rest of this chapter, more particularly on the connection between the occurrence of volcanic rocks and the configuration of the surface. This subject may appear to be beyond the scope of this paper. But the examination of every question which relates to the inner connection between the phenomena attending the ejection of volcanic rocks will aid in disclosing the true nature of these, and promote the knowledge of the principles of their natural system. We will endeavor to answer the following questions: Was the particular structure of certain portions of the crust of the globe, which is indicated by the situation of elevated regions on its surface, among the causes of the eruptions of volcanic rocks? or were the inequalities of level on the surface, in the volcanic regions, due to the processes attending and the agencies causing the eruptions?

The answer to both questions must be in the affirmative. The peculiar structure of the earth's crust, at those places where mountain ranges and highlands rise on its surface, appears to have influenced in a great measure the distribution of the volcanic rocks, because those among them which are accompanied by the latter, had been elevated before the time of the eruptions, and the adjoining lowlands were not the theater of eruptive activity. But, on the other hand, it is evident that the ejection of volcanic rocks, or rather those subterranean processes of which they were one of the

---

acter in rocks and scenery to that which that range has in other parts. It appears that a gap of more than one hundred miles in length has been formed in the region of the two volcanoes, by the displacement of a portion of the Sierra Nevada, which was probably bounded by two lines of fracture transverse to the direction of the mountain range, and has subsided thousands of feet, and that then an immense accumulation of volcanic rocks filled up the gap, and closed in building up the two giant volcanoes. Other lines of dislocation which have given vent to volcanic rocks, and which have more frequently been noticed, are directed parallel to mountain ranges. Of such nature appears to be the abrupt descent of the Sierra Nevada towards the Great Basin, which has been the theater of violent eruptive action; and probably the relations on the western slope of the Rocky Mountains are of a similar nature. The Vihorlat-Gutin Range, in Hungary, offers a striking illustration of an extensive accumulation of volcanic rocks along the foot of a preëxisting mountain range, though the dislocation is not conspicuous in that country, on account of the deposition of recent sediments which filled up the Hungarian Basin. There may be some affinity between these modes of occurrence of volcanic rocks and the manner in which they are met with in certain areas of flat or hilly countries, surrounded by ranges composed of ancient rocks. The best illustration is afforded by the Basin of Transylvania. The undulating country of the interior is encircled by high ranges consisting of ancient formations, which are lined on their inner side with volcanic rocks. Hungary itself affords a similar instance, though less regularity is perceptible; and the same structure is somewhat approached in the geological relations of Bohemia. We may also mention, as recalling that mode of occurrence, certain depressions between the two summit ranges of the Sierra Nevada, such as the Basins of Sierra Valley and Lake Tahoe, which are encircled, first by a ring of volcanic rocks, and then only by the metamorphic and granitic rocks which form the bulk of the Sierra Nevada. Or the "Parks" of the Rocky Mountains. Their geology, it is true, is almost unknown. An interesting description of the San Luis Park, the greatest among them, recently published (see American Journal of Science and Arts, November, 1867), shows that the elevated rim of its basin, which is estimated at eighteen thousand square miles, is made up of ancient formations, and that volcanic rocks encircle more immediately the extensive plain forming its bottom, which is itself composed of volcanic sediments, thus completing a structure that reminds of that of Transylvania, in more than one respect. If we look for instances on a grander scale, we may find some analogy with the mode of occurrence of volcanic rocks as just described, in the volcanic ranges encircling the Basin of the Pacific Ocean. And it may not be out of place if we call attention to the similarity with these circular basins which is presented by the configuration of the surface of the moon.

resulting events, exerted a powerful reaction upon the further promotion and acceleration of those motions of the crust by which the irregularities of level of the surface were produced. This may be inferred, in the first place, from the fact, that in and along volcanic belts, elevation and plication of sediments have taken place, probably in every instance; both modes of disturbance have affected, partly sediments anterior in age to the eruptive action, and partly such as were contemporaneous with and posterior to it; and there may be frequently noticed a diminution of the intensity of these disturbances, in an inverse ratio with the distance from the volcanic belt.[29] But besides this fact, observation has placed it beyond doubt, that in the second half of the Tertiary period, and after it, a greater aggregate amount of relative, and probably too of absolute elevation has taken place generally over the globe than had been the case for ages before. The altitude of the rocks composing the summits of the highest mountain ranges and table-lands of the present time, exceeds that which they had in the

[29] This evident connection, in volcanic regions, of elevation and plication, as cause and effect, appears to be one of the gravest objections against the general validity of the theory of Mr. Hall on the mode of formation of mountain ranges, though the incongruity of an explanation of the granitic wedges by metamorphism *in situ* with the chemical nature of granitic rocks, the total insufficiency of a gradual sedimentary deposition for accounting for a foot-for-foot subsidence of large areas, and the difficulty of finding any natural cause of the assumed fact that the belts of greatest amplitude within each area of subsidence should have been elevated to mountain ranges in preference to other neighboring parts, are objections of scarcely less weight. It is a well-established fact, that the Alps existed as a mountain range, at least from the time of the Jurassic period (though probably long before it), and have gained in height in later periods. Yet the Jurassic and Cretaceous strata are as much contorted as are those of more ancient age, and the same is true in a still greater measure of the Tertiary Flysch. If, therefore, Mr. Vose, in his Orographic Geology (p. 68), arrives at the conclusion: "So far as we have examined the facts, no other hypothesis than that of the slow sinking of vast masses of yielding sediments can at all satisfactorily account for the plication and other evident effects of a compressive force so invariably exhibited in mountain districts," the more recent formations of the Alps confirm this view as little as the above-mentioned example regarding the volcanic belts. It may be mentioned, in this connection, that, while Mr. Hall's theory would necessarily imply an increase in the intensity of plication towards the axis of greatest accumulation, which is considered by him to have been coincident, after the elevation, with the axis of the mountain ranges, this conclusion is not confirmed by the structure of the Alps. In Vorarlberg and northern Tyrol, which offer probably, of all parts of the Alps, the most normal and regular structure, all strata, commencing with those of Triassic age, are least disturbed where they are nearest to the axis, and the plication increases towards the foot of the range. Superposition, by contortion, of older formations on those of more recent origin, is encountered with increasing frequency of instances and growing distinctness, in crossing the parallel waves from those nearest to the axis, towards the northern foot of the range. Another objection, nearly related to the foregoing, is this, that, granting that a trough-like depression would be able to cause plication by the settling of the yielding strata towards the axis of greatest subsidence, the waves thereby formed would have their steeper inclination towards that axis, and their flatter slopes directed outwardly, since a greater resistance would oppose the motion of the lower strata than would be offered to the higher ones. The analogous instance, to which reference has been made, of a wave rolling towards the beach, shows plainly the effect of the retardation suffered by the lower portion of the water by friction, in the steepening of that side nearest to the place towards which motion is directed, and the final throwing over of the top in the same direction. A familiar instance, which repeats more exactly, though on a small scale, the conditions suggested by Mr. Hall's theory, is afforded when a viscous mass, such as resin or pitch, moves downward on a slightly inclined plane. If the necessary conditions are given for the formation of waves, their steeper sides will always be on the lower end, or, on that which would be nearest to the axis of a trough-like depression. It is obvious that this shape is the reverse of that of the waves of plication which Mr. Rogers and others have observed, and on which even Mr. Hall's theory is partially founded. This theory, which was first proposed for a mountain range in which recent formations do not occur, and where, therefore, not all of these objections could be raised, may, if somewhat modified, have its limited applicability for partially explaining the mode of formation of certain mountain ranges; but numerous arguments appear to preclude its general applicability, especially so in the case of the European Alps, and probably not less in the case of the Himalaya. It appears, too, to be quite inadmissible in the case of the Rocky Mountains; and as regards the Sierra Nevada, only a chain of the most arbitrary assumptions would be able to give it an apparent validity for the explanation of any features in the structure of that range.

Cretaceous period by thousands of feet. This is not only true for those ranges which, like the Andes and Rocky Mountains, have been intensely volcanic, but also for such as show a less immediate connection with eruptive activity in the volcanic era, as is the case with the Pyrenees, the Alps and the Himalaya. The elevation which succeeded the Cretaceous period appears to have everywhere been slow, intermittent, and partly retrograde, in the Eocene epoch, while its chief phase is traceable to the Miocene and subsequent epochs, by the relative altitude above the level of the sea to which sediments of different ages have been raised.

There can scarcely be any doubt that this acceleration of the changes of level, and the extrusion of volcanic rocks, have had an intimate connection. But the mode of this connection has by no means been ascertained, and appears to be quite an intricate subject. It was formerly believed that the eruptive rocks were themselves the upheaving agents, their intrusion and ejection having been the mechanical means of the elevation of mountain ranges. But geological observation and argumentation have conclusively demonstrated that such could not be the case, and made it probable that both elevation and eruption are the most conspicuous symptoms of different agencies which were dependent on one common cause. When that first theory had to be abandoned, another was put in its place, to the effect that the ejection of rocks must have been attended by subsidence ; and, although we shall show in the following pages that the rise of the crust greatly predominated in the vicinity of the eruptions, there can be no doubt that subsidence was probably in all cases among their intricate effects. But the cause generally ascribed to it is not at all capable of explaining it. The assumption that eruption must be attended by subsidence is usually made on the ground, that the removal of a certain volume of matter by ejection, from a deep-seated place, would cause the formation of a vacuity, corresponding in extent to the volume removed, and that consequently the overlying portions of the crust would settle down. This assumption appeared to be corroborated by the observation that the region surrounding a volcano subsides during its activity, while it rises in periods of rest. But it is evident that the size of a current of lava is not proportionate to the settling of an area of hundreds of square miles to the amount of several feet. If, moreover, the views here advocated, regarding the cause and mode of eruptive activity, are correct, that is, if the ejection of rocky matter is the effect of the increase of volume which it undergoes on passing into the state of aqueous fusion, then the eruption is only the discharge of the surplus matter which has no room within the space of the fissure ; no vacuity could therefore be formed, and the commonly adopted cause of the subsidence would not exist. There are, however, two other causes which would produce subsidence, and have probably been acting in every case of massive and volcanic eruptions. The first of them is the contraction of the liquid mass in the conduits, by cooling. Its amount must be considerable in proportion to the space of the fissure, but small when compared with the volume of a mountain range on the surface. Its effects will be local and abrupt. In the case of volcanoes, it is the probable cause of the familiar phenomenon of the subsidence of the bottom of craters, and of those less frequent cases where whole portions of the cone are suddenly engulfed. As regards extensive accumulations of rocks by massive eruptions, there are certain features of

the configuration of their surface which cannot be more plausibly explained in any other way. To these belong the sudden breaks in the continuity of their surface, which consist sometimes in elongated and steep walls, thousands of feet in height, and miles in length, or in crateriform or semi-circular basins, and in other more or less abrupt depressions, which may be chiefly noticed where large regions are uniformly covered with granite, porphyry or volcanic rocks. This cause will affect the mass of the eruptive rock itself, but not perceptibly the surrounding country. Yet, this is subsiding when a volcano is active, and it can be definitely proved in the case of the andesitic ranges of Hungary, that during the epochs of the massive eruptions, the general rise has been repeatedly interrupted by the subsidence of the surroundings of the theater of activity. To these changes applies probably the second of the causes alluded to. Whenever a fissure is filled by liquid matter injected from below, its surroundings must necessarily become heated, and, by their expansion, produce a slight increase of the rise of the surface. This heat escapes, in the case of a volcano, chiefly in the epochs of its activity, by the emission of lava, vapors and boiling water, and other phenomena associated with volcanic action. Massive eruptions will have been attended by the escape of heat on a much larger scale. They appear to have been often accompanied by an extremely violent emission of hot water, as may be inferred from the great accumulation of deposits of silica in some volcanic countries, or from the immense overflows of extensive regions by volcanic mud: this occurs in Hungary and on the western slope of the Sierra Nevada on so grand a scale as to almost exclude the possibility of its having originated merely from volcanic action, especially as no volcano is visible from which they could have escaped. These processes must of course have had the effect of lowering the temperature of the masses surrounding the fissure to some distance from it, and of producing subsidence during the eras of activity. Yet they are not sufficient to explain the extent to which it has often taken place, though it had in no case, in the vicinity of the theaters of eruptive action, more effect than to reduce locally the amount of elevation.

A few examples will suffice to show how vast are the changes of level which have taken place since the commencement of the volcanic era, and to demonstrate their connection with the other manifestations of vulcanism during the same era. An instructive instance is furnished by the country situated between the Pacific coast and the Rocky Mountains. The labors of several distinguished geologists have made us acquainted with some of the main features of its complicated structure; but it is only by the detailed examination of some of the most important portions, together with the accurate determination of the age of several of the sedimentary and metamorphic formations, made by and under the direction of Professor Whitney, that the foundation has been laid for an exact exploration of the entire western part of North America, which is now proceeding with rapid steps, and promises to give important contributions towards the solution of the questions discussed in this essay. There appears to have existed, as we mentioned before, an ancient granitic era in that region. But it is as yet impossible to recognize the relation of this ancient granite and the metamorphic rocks by which it is accompanied to the ancient or to the present configuration of the surface. In the western countries, those formations are concealed by the immense overlying

accumulation of Palæozoic and Mesozoic sediments, and the subsequent denudation of these, though grand in the extreme, has only been sufficient to expose to view the ancient granite in some localities, among which we mentioned that on the Colorado River. Other masses of ancient granite are visible at the surface in numerous places in the Great Basin, but their exact relations still remain to be determined, while in the Rocky Mountains they are one of the prominent features, partaking largely in their structure.

The next period of interest, in regard to the occurrence of eruptive rocks, is that of the deposition of Triassic and Liassic sediments in great aggregate thickness, which were found by Whitney to extend from the Pacific coast far into the Great Basin. They prove that all this country was then still submerged beneath the sea, while the Rocky Mountains formed probably a broad belt elevated above it. It is in this period that were ejected the quartzose porphyries of the County of Plumas, in northern California, almost contemporaneously with those of the southern Alps. Whether this event, which was probably not limited to the region mentioned, was attended by any changes in the configuration of the surface, cannot yet be decided. After it, however, they must have taken place on a grand scale, reminding one of the emergence of the central body of the Alps from the sea after the deposition of the infra-Liassic limestones. The ejection of granite found, it appears, almost the whole country embraced between the western slope of the Sierra Nevada and the eastern slope of the Rocky Mountains lifted out of the sea. But changes greater than those which had preceded them, appear to have attended and followed those gigantic outbreaks. They were probably due, in a great measure, to the intense metamorphism which was connected with them, and has completely changed the petrographical character of the preceding sedimentary deposits. When the volcanic era commenced, which was probably in the Miocene epoch, all the ancient formations of the Sierra Nevada were nearly turned upon their edges, and the depressions of the surface in the Great Basin were filled with salt water. But the altitude of the entire plateau above the level of the sea was probably insignificant at that time compared with what it is now, as may be inferred from the fact, that rivers did then flow on the present western slope of the Sierra Nevada, parallel to its crest, which they could not have done if that slope had had its present inclination. We must imagine that where the great mountain range raises now its lofty summits, a hilly country extended then, ascending slightly to the east. The first outbreaks of volcanic rocks found those rivers still flowing in their beds, as is proved by the higher sediments in the old river-channels, which consist of volcanic tufas. But great changes occurred after the first commencement of the volcanic era, changes which contributed probably more towards imparting to the western portion of North America its present features than any which had preceded them. The volcanic belt extending along the entire western coast of America, had its greatest breadth between the coast of California and the Rocky Mountains, and the eruptive activity has been violent over that vast region. It appears that to that era is due the principal part of the elevation of the high table-lands. Such, at least, is the case in their western portion. The crest of the Sierra Nevada must have been elevated at a quicker rate than its western foot, as distinct traces are left in the gravel deposits that those ancient rivers which were flowing parallel to its crest have

been gradually turned from their channels, overflowing their banks at several places in succession, and taking a course down the slope, until an entirely new system of water-courses was created, at right angles to the crest, the steep ravines and gorges of which are now one of the characteristic features of the Sierra Nevada. It appears that the changes of level since the inauguration of the volcanic era have also been progressing on a grand scale in the eastern part of the Great Basin, where the eruptive activity had probably even more gigantic proportions than in the west. The central portion of the Rocky Mountains was raised, according to the estimate of Dana, about seven thousand feet since the Cretaceous ; and its eastern part from one to two thousand feet, since the Miocene, according to the observations of Hayden.

These figures render evident the great elevation which the mountain mass between the Sacramento and the Missouri must have undergone since the commencement of the volcanic era. Twice in the history of that country, since the Triassic period, may there be recognized an extraordinary intensity of all those changes which we must ascribe to subterranean agencies. The first instance was in or about the Jurassic epoch, when strata, which appear to have been quietly deposited during preceding eras, were elevated, and a gigantic intrusion and ejection of granitic masses was attended by an intense and wide-spread metamorphism, by which disturbances and plications were promoted; the second, in the volcanic era. It is probable that similar phases to those mentioned will be recognized throughout the entire range of the Andes, the geological structure of which appears to offer much similarity in different parts. To the events of the volcanic era, chiefly, will have to be ascribed the connection of both parts of the continent, though it may have been prepared by that preceding era of intensified actions, which manifested itself in the ejection of the granite of the Sierra Nevada, and appears to have left no less distinct traces in other portions of the range of the Andes. We may still note a peculiar difference in the mode of the changes of level if we proceed across the continent from west to east. It appears that the narrow strip of land adjoining immediately the western coast has been subjected rather to periodical oscillations than to any lasting changes of level, while the great elevation of the mountain ranges and highlands must be chiefly ascribed to the circumstance that all changes have acted there essentially in the same direction, producing the elevation of extensive regions. This would explain why the western descent of the Andes has been periodically increasing in steepness and the strip between them and the coast is of little width. The latter appears to correspond to the boundary between an area of elevation to the east and an area of subsidence to the west, one of which was especially subjected to the manifestations of vulcanism, while in the other it has left no recognizable signs. It is quite different on the eastern side of the range of the Andes, where, in both parts of the continent, a slow rise has taken place, which has connected, during the volcanic era, that mountain range with other ranges farther east, by those extensive low-lands which are so important a feature as regards the extraordinary productivity of both parts of the continent.

Similar to these are the relations presented by the European continent, in regard to which we will only mention a few prominent facts. During the porphyritic era and the time immediately succeeding it, great changes of level had taken place on that

continent. It appears that in Middle Germany the Triassic period designates the commencement of an era of repose, while in the Alps, where the porphyritic outbursts took place in the Triassic age, the Liassic strata still participated in the disturbances and elevations, which partly attended the porphyritic era and partly succeeded it. Thereafter followed another period distinguished by the comparatively small amount of disturbances which took place in it. Subsidence appears to have prevailed in its first part, while towards its end, during the second half of the Eocene epoch, that renewed rise commenced which contributed so much towards imparting to that mountain range its present configuration. In surveying the general features of the geology of Europe, it will be found that the changes of the boundaries of the continent and the sea, as produced by rise and subsidence, have, in the period intermediate between the porphyritic and the volcanic era, been inconsiderable in proportion to the length of time; and, though grand in the totality of their results, they are probably far surpassed by those which have been produced since propylite reopened the eruptive activity. None of the prominent mountain ranges, it is true, have been called into existence since then. Some of them, of little importance and consisting completely of volcanic rocks, have been formed, and sedimentary formations have been folded quite extensively, so as to form hilly regions ; but the main ranges had existed before, and only underwent an increase in volume, though one of considerable magnitude, and the rate of elevation appears to have been greatest with those mountain ranges, during the period indicated, which have the greatest altitude at present. The amount of elevation which Eocene and Miocene strata have experienced in the Alps, Pyrenees, and others of the prominent mountain ranges justifies this conclusion, while the mode of occurrence of these formations in the Alps allows us to infer that their central portion was elevated at a more rapid rate than either the northerly or the southerly part. It is worthy of note that not alone in the Alps, but quite generally in Europe, the Jurassic and Cretaceous strata have undergone only little more disturbances than those of Eocene age. In the belts elevated during the volcanic era, all three formations participate ordinarily at nearly equal rates in the structure of the low ranges of the hills stretching between the main ranges and girting their foot. The conclusion appears therefore to be justified that in the volcanic belts, at least, the elevation of the Jurassic and Cretaceous has chiefly taken place during the volcanic era.

There may be distinguished a twofold mode of elevation in the volcanic era : it manifested itself either in a secular rise of continental areas, or in the elevation of mountain ranges, as may be exemplified by referring to the difference in the mode of elevation between the Andes and the countries adjoining them to the east.

The distinction is not so definite if we refer to the European continent. Among the regions elevated during the volcanic era may be chiefly noticed a broad belt extending from the Alps through the Turkish Peninsula, Asia Minor, Armenia, and Persia to the Himalaya, and continuing less distinct westward to the Pyrenees. The three main ranges have experienced the greatest amount of elevation within this belt. The rest of it, which is distinguished by the folding of the Nummulitic strata over its entire area, marks the region of the next greatest intensity of the elevating forces within a much more extensive area of continental rise. The increase of altitude has been com-

paratively inconsiderable over this area; yet it is, in its totality, of greater import for the configuration of the surface of the planet than the production of the mountainous and hilly regions mentioned. For it had the effect of connecting regions which were before separated by the sea, and of increasing thereby the area of continents in certain directions. It is well known that the sea, which in the beginning of the volcanic era extended in the valley of the Danube to above Vienna, bathed both slopes of the Carpathians, and reached eastward to the foot of the highlands of Central Asia, has since then considerably retired, and that the secular rise of northern Africa, Arabia, and Asia Minor has, also in these countries, enlarged the continental areas.

So much time has elapsed, in most countries, since the main phases of the volcanic era, that the influence of the events connected with them upon elevation and subsidence has probably relaxed. It appears that portions of the areas of elevation have suffered a periodical subsidence, not only since that time, but also during the volcanic era. But its aggregate amount having been in most of them less than that of elevation, the final effect manifests itself generally as a rise; though it appears that in recent times some regions, chiefly those which are situated on the northern and southern boundaries of the great area of continental elevation, are undergoing a more marked subsidence. Even now, however, those countries chiefly are rising which were distinguished by eruptive activity in the volcanic era.

These few instances will suffice to show how great have been the changes in the configuration of some portions of the surface of the globe during the relatively short geological time which has elapsed since the commencement of the volcanic era, and how much superior they appear to have been to those which had been going on during preceding periods of much longer duration. Those facts which are known in relation to this subject, allow to infer, that the changes of level were proceeding at an accelerated rate, during, and probably also in the time next preceding, the volcanic era, and that the elevation was limited to certain belts of great extent which were, in the majority of cases, distinguished from neighboring regions by eruptive activity. But this is not true for all cases, since there are some regions the elevation of which was especially grand, and in which very few rocks, or none at all, were ejected. In examining into the causes of the connection of elevation with the other events of the volcanic era, we must therefore keep in view the distinction of those cases where it was attended, and those where it was not attended, by eruptive activity.

As regards the first cases, we may refer for their explanation to our previous theoretical considerations of the causes and effects of the formation of fractures. If the increase of volume by the slow and perfect crystallization of viscous masses below the crust was the cause of the rending of fissures, a slow rise must have preceded this process. That this was so on the European continent, is verified by the fact, that the Eocene strata had been elevated quite considerably when the first of those sediments, which can be proved to have been contemporaneous with eruptive activity, were deposited. If then the relief from pressure caused the extensive crystallization, at the depth to which the fissures reached, of masses which had been held before in a viscous condition by the pressure itself, an accelerated rise would be the effect; and if

the repeated rupturing of the crust caused a repetition of this process, in the way indicated before, epochs of an accelerated rise would alternate with those of a retarded elevation. This theory will explain why a very considerable rise, and of greater extent than that which had preceded, attended the phenomena of the basaltic epoch.

Although we must consider this subterranean process as the chief cause of continental elevations, so far as they attended the phenomena of eruptive activity, it was certainly not their only cause. There can be no doubt that the process of metamorphism must have promoted those changes. As far as we understand the conditions required for its production, it appears that they could not be created by any other known processes in a degree similar to that in which we must necessarily suppose them to have attended the ejection of rocks, whether its mode be that of massive eruption or of volcanic activity. Even on the surface there are no places where we can observe, at the present time, metamorphic processes of greater intensity than near the orifices of volcanoes, or in solfataras, or at the theaters of other processes attending or succeeding volcanic activity; nor is there at any other places more evidence afforded of subterranean metamorphic processes. The latter will exceed those visible on the surface in nearly equal proportion with the increase of temperature and pressure in depth; while we may conclude theoretically, that the neighborhood of fissures filled with heated substances from below would not only have a higher temperature than other portions of the crust, but also allow of a comparatively free circulation of water, on account of its shattered condition. In respect to metamorphic action, as in all other respects, the grandeur of the phenomena of massive eruptions would make us presuppose that they would have given rise to a far more extensive and intense metamorphism than the insignificant processes of volcanic activity. The occurrence of ancient eruptive rocks in belts of highly metamorphosed sediments removes it almost beyond doubt that they are connected in the relation of cause and effect. It is assumed that metamorphic processes, on account of the entering of water into the composition of rocks, and their crystallization, must be attended by an increase of volume, and will have the mechanical effect of elevating the surface.

We may thus obtain a few hints as to the causes of the changes of level which those portions of the surface of the globe which were the theater of eruptive activity in the volcanic era, have undergone since its inauguration. The agencies to which they were due must be even more intricate than the motions of the crust, because the movement in one direction may be the resultant of several forces working in opposite directions. Increase of volume by crystallization below the crust, in those regions where the formation of fractures relieved the masses from pressure, is probably the most potent of these agencies. Metamorphism would work in the same direction, while loss of heat would cause subsidence. All these agencies have their first and common cause in the formation of fractures by an upward tension, and all other phenomena of vulcanism are the immediate or mediate effects of that same cause, which itself results from the gradual cooling of the globe.

There remain those cases to be considered where some of the most prominent mountain ranges, in the structure of which volcanic rocks take no part, were elevated during the volcanic era, at a much greater ratio even than those in which these rocks

occur. The Alps and the Himalaya are the most striking instances of this kind. The first of these, and probably, too, the other, had, as we mentioned before, undergone a considerable elevation in and after the porphyritic era, but have probably changed their altitude very little in the next following periods. The acceleration of their elevation during the volcanic era appears, however, to have greatly exceeded that of the Andes. The coincidence in time of these events, and of all the phenomena characteristic of the volcanic era, justifies the supposition that they are connected in their origin.

If we contemplate, in its relations to the volcanic era, the great elevated belt of which the Alps and Himalaya form the axis, we find it to consist of three parallel zones. The central one comprises those two mountain ranges and the broad mountainous country which connects them, and which owes its configuration chiefly to the events of the volcanic era. The Alps and Himalaya are free from volcanic rocks. This is also true as regards the central portions of those chains which branch off from the Alps in a southeasterly direction, and of those (as far as their geology has been explored) which extend westerly from the Himalaya. The farther one proceeds in the Turkish peninsula towards the east, the more frequent are the monuments of eruptive activity of the volcanic era; they are known in Servia and Bulgaria, in the north, and in Macedonia, Thracia and Epirus, in the south. They increase in similar ratio as one proceeds westerly from the Himalaya, through the highlands of Armenia to Asia Minor. If it is considered that active volcanoes are particularly numerous in those regions where the elongated portions of two different continents have, as it were, a tendency to connection, the analogy with the mode of distribution of volcanic rocks in the regions mentioned is conspicuous. The system of the Alps with its southeastern, and that of the Himalaya with its western branches, were disconnected before the Tertiary period, and were united into one mountainous belt during the same. The eruptive activity contemporaneous with this slow process was remote from the main axis where this had existed as an elevated range before, and approached it more and more, from both sides, increasing, at the same time, in intensity, until it culminated in that region where the connection of both systems was effected. Massive eruptions and volcanic activity have ceased completely in this central zone.

North of this, is another zone, which was distinguished in its entire length by the intensity of eruptive action in the volcanic era. It stretches from Central Asia by the Caspian Sea, the Caucasus, the Crimea, the Carpathians and, in branches, through central Germany to central France. In the European portion of this zone, there are only recognizable in thermal and mineral springs the last feeble remnants of former volcanic activity, while they are somewhat more energetic in that portion which is situated on the Asiatic continent. A third zone, not less distinguished for the intensity of eruptive action in the volcanic era, accompanies the main axis to the south. It traverses India, and, in the Bay of Bengal, is connected with the volcanic belts of the Indian Archipelago, while it continues to the west through Arabia, Syria, Palestine, to the Mediterranean, where it comprises the active volcanoes of the Grecian Archipelago and Italy, and is connected by Sardinia and southern Spain with the Azores. Volcanic activity still continues in this belt, but the period of the massive eruptions has passed long ago.

The entire belt, composed of these three zones, has to be considered as one great area of elevation, characterized, at the same time, over its greater portion, by the remnants of the eruptive activity of the volcanic era. No portion of it, however, has, as we mentioned before, experienced an amount of additional elevation during that period equal to that of those mountain ranges which existed before it, and among which the Alps and Himalaya are the most prominent. In these cases there cannot have been any connection between the elevation and the ejection of the rocks to the surface, because these do not occur. But this does not preclude the connection between the elevation and those agencies which are the causes of eruption. It has been often demonstrated that the changes of level must have been accompanied by the formation of such fractures as would be closed next to the surface, and, though allowing of an intrusion of plastic matter from below, would prevent its extrusion to the surface. It is probable that fissures of this kind may have been chiefly formed where high mountain chains are composed of metamorphic rocks, since they frequently exhibit vertical dislocations, partly parallel to their axis, and partly at right angles to it, by which the strata on one side have been moved thousands of feet above the other, and which, notwithstanding, did not give vent to the ejection of rocks. These faulting fissures appear to form frequently the lateral boundaries of mountain ranges and the limits of the manifestation of vulcanism, and both these circumstances allow us to infer that they extend downward to great depth. Though one of the main features in the geological structure of the Alps, they have hitherto been little examined. But it is probable that their formation was coincident in time with the main phase of elevation, that is, with the volcanic era. If, then, in that part of the crust over which the Alps are elevated, such fractures were formed as did not open on the surface, then all the agencies below would coöperate towards elevation alone. The expansive force produced by aqueous fusion would find no vent for the discharge of the masses by which the volume had increased, nor would there be any opportunity given for the escape of heat by hot water and other means; while, on the other hand, the masses in depth would be relieved from pressure by the formation of this kind of fractures in the same way as by those which would allow the passage of liquid matter to the surface. In the case of the latter, an immense amount of force is spent in other modes of action, while in the first case it could be applied almost exclusively to elevation. Besides this direct action, however, we must also keep in view, that in those regions where fissures would not be open at the surface, the conditions required for metamorphic action would be given on a particularly grand scale. Gases and water would not reach the surface, but be employed in depth in promoting metamorphic action over vast regions, and increasing the rate of elevation. It may be by processes of this kind that already in ancient times, contemporaneously with an accelerated elevation, were formed those granitic wedges surrounded by broad belts of foliated metamorphic rocks, which are peculiar to certain mountain ranges, particularly to those which also in the volcanic era have not been the theater of eruptive activity. The intrusion, from below, of heated masses into fissures closed towards the surface, would give all the conditions required for the exhibition, on a grand scale, of those processes of hydropyric metamorphism which Daubrée has rendered probable by his experiments and theoretical deductions.

Leaving aside these theoretical considerations, and comparing only the different facts mentioned in regard to the changes of level which have taken place on the surface of the globe since the inauguration of the volcanic era, we are forced to the conclusion that they must be intimately connected, as regards their causes, with the other phenomena by which this era was distinguished from preceding periods. Elevation and eruptive activity, even when locally not quite coincident, are coördinate effects of the cooling of the globe ; but while the one is its immediate effect, the other results from it only by the concurrence of other agencies, which by themselves alone would have been incapable of producing results of such magnitude. As there are distinct phases in the history of eruptive action, dependent on and marking the evolution of the globe, so we may recognize different stages in the mode of manifestation of the elevating forces. In those elevations which took place during the volcanic era, there are certain peculiar features evident, among which may be mentioned : the increase in altitude of those mountain ranges included in the volcanic belts ; the union into one main chain of several smaller ridges, the axes of which are situated on a line ; the lateral connection of parallel ranges into highlands ; the oblique connection of the ends of main chains, the axes of which are situated on parallel lines, but are remote from each other longitudinally, by broad belts of mountainous regions (of this character is the connection of the Alps and the Himalaya) ; the elevation, finally, above the level of the sea, of large areas which had been submerged before, whereby distant mountain ranges were connected by extensive lowlands, the size of the continents increased, and their outlines rendered more uniform. The mode of these great changes of the configuration of the surface of the globe was probably a repetition on a large scale of similar changes which had been going on in former eras of eruptive activity. It is not our object here to develop them. But throughout the course of these changes there appears to be conspicuous a tendency to connect, in certain directions, what was before disconnected, to increase in size and render more definite certain areas of elevation, and to separate them from other areas of subsidence, which appear to have been likewise increasing in extent. We may even recognize an increase of this tendency during the volcanic era, as the phenomena connected with the basaltic epoch have been far more widely and generally distributed over the areas of volcanic belts than those of the preceding (propylitic and andesitic) epochs. There must be certain general laws which regulate the directions in which the connection of disconnected parts takes place. Their knowledge is still very limited. The admirable manner in which Dana has laid out the grand outlines of the arrangement of the islands of the Pacific, has indicated the way by which we may look for the solution of this problem. If the structure of the crystallized crust of the globe gives the most probable cause of the definite directions which may be recognized in the outlines of continents and chains of islands, it should be borne in mind, that the direction of structural planes, if they exist, must vary gradually in depth, in the same ratio with the chemical composition, and that they may at the depth of andesitic compounds be different from what they would be in the granitic depths. The singular way in which the connections by elevation are effected, and which has been already partly pointed out by Dana, appears to

find only an explanation when such changes of the direction of the structural planes are assumed to take place in depth.

The tendency to simplify beyond their present conditions the general outlines of the configuration of the surface of the globe, continues probably without intermission, though an era of comparative repose has followed the violent exertions of vulcanism of the volcanic era. The great backbone of the Eastern continent, comprising the Alps and the Himalaya, and the second great belt which comprises the Andes, and, more properly, encircles the whole Pacific Ocean, are at the present epoch the main features in the orography of the globe. Both have derived their prominent position from the events of the volcanic era. The conclusions at which we have arrived in these pages have been drawn chiefly from observations made in regions of prominent interest in either belt, and it is for this reason especially that we believe that at least some of them will be found to be susceptible of general application.

I am fully aware how imperfect is this attempt to develop, in the correlations of the volcanic rocks, the principles of their natural system. This system should be, as we remarked before, not a classification of objects by certain conspicuous properties, but a classification of objects by their definite mutual relations. We have not to make the divisions, but to find them. We shall be able to do this with greater or less perfection, in the same measure as those relations are studied and firmly established. Much is needed to arrive at this end. It can only be achieved after evidence has been accumulated by the combined and harmonious labors, in different countries, of geologists in the field as well as in the laboratory. The range over which both modes of observation extend from year to year, and the field on which their results meet, is increasing in a surprising degree. Yet eruptive rocks form ordinarily an object of less exact observation than those of sedimentary origin; and it cannot be denied that harmonious observation, by which alone can be established the principles of comparative petrology, is rendered nearly impossible, as long as no uniform system of nomenclature is applied. These pages are the result of an attempt to add one more to the many contributions towards establishing the foundation of both, and to show the value which the study of eruptive rocks and of those mutual relations which comprise their natural system promises to have for approaching the solution of some of the highest problems of geological science.

TABLE OF CONTENTS.

PAGE.

Introductory 1

The Natural System of Volcanic Rocks 5

Order First: Rhyolite 12

Order Second: Trachyte 17

Order Third: Propylite 20

Order Fourth: Andesite 25

Order Fifth: Basalt 26

Correlation of the Five Orders of Volcanic Rocks 28

Laws Relative to the Age of Massive Eruptions 29

Laws regarding the Mutual Relations of Massive Eruptions and Volcanic Activity 32

Relation of Volcanic Rocks to Ancient Eruptive Rocks 35

Correlation of Age and Texture 39

Correlation of Age and Composition 41

Correlation of Eruptive Rocks in regard to their Geographical Distribution 43

On the Origin of Volcanic Rocks 46

1. *Origin of Massive Eruptions* 47

2. *Origin of Volcanic Action* 60

3. *Other Theories regarding the Origin of Volcanic Rocks* 68

Relation of the Distribution of Volcanic Rocks to the Configuration of the Surface of the Globe 78

MEMOIRS

OF THE

CALIFORNIA ACADEMY OF SCIENCES

Volume II

SAN FRANCISCO
PUBLISHED BY THE ACADEMY
1888 – 1896

CONTENTS OF VOLUME II.

PAGE

I. ON THE ANATOMY OF SUTROA ROSTRATA, A NEW ANNELID OF THE SUB-FAMILY LUMBRICULINA. *By Gustav Eisen* 1

(Published January, 1888.)

II. ON SOME ANCIENT SCULPTURES FROM THE PACIFIC SLOPE OF GUATEMALA. *By Gustav Eisen* 9

(Published July, 1888.)

III. ON CALIFORNIA EUDRILIDÆ. *By Gustav Eisen* 21

(Published February, 1894.)

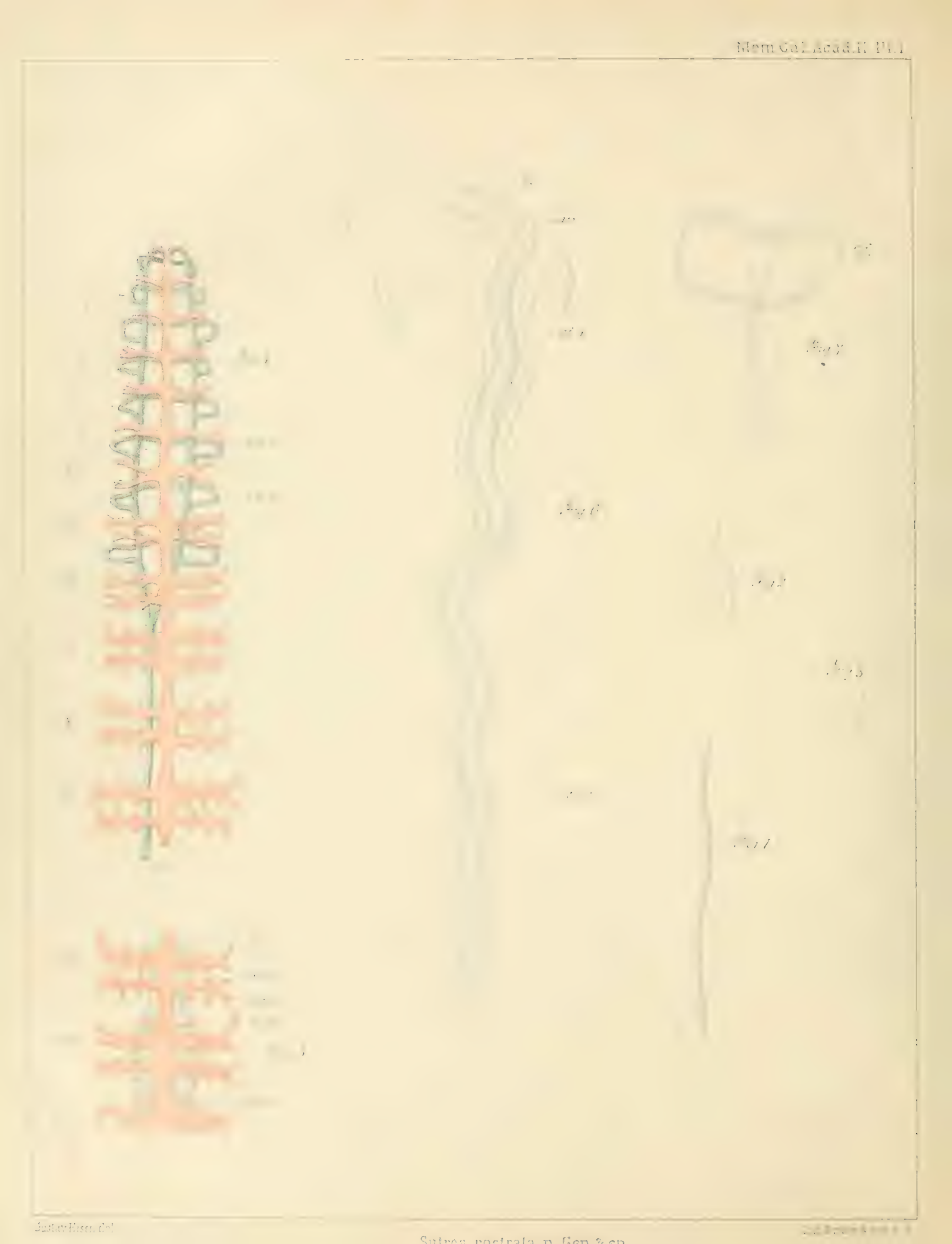
IV. PACIFIC COAST OLIGOCHÆTA. I. *By Gustav Eisen* 63

(Published March, 1895.)

V. PACIFIC COAST OLIGOCHÆTA. II. *By Gustav Eisen* 123

(Published February, 1896.)

INDEX OF SCIENTIFIC NAMES 199



Sutura vestrala n. fig. 8 en

I. On the Anatomy of Sutroa rostrata, a New Annelid of the Family of Lumbriculina.

By Gustav Eisen.

The oligochætous annelid, which is the subject of this monograph, was first found by me some ten years ago in the small body of water known as Mountain Lake, situated close to the Marine Hospital, on the Reservation west of San Francisco, California. During a recent visit to the same locality, in May, 1887, I found the same worm in exactly the same part of the lake, but, as before, in very few specimens. Perceiving the necessity of creating a new genus for this oligochæte, I have done myself the honor to dedicate the same to Mr. Adolph Sutro, whose magnificent public scientific library, marine aquarium and zoölogical station on the Pacific Coast will in the near future become one of the most prominent and valuable institutions of learning in this country.

OLIGOCHÆTA.

Family. **Lumbriculidæ.**

A. Sub-family Trichodrilina Vejd.

No solitary albuminous gland opening on the ventral side of the body.

B. Sub-family Lumbriculina Vejd.

A solitary albuminous gland opening on the ventral side of one of the anterior segments. Of this sub-family three genera are now known:

1. **Lumbriculus** Grube

Four pairs of seminal receptacles in segments 8, 10, 11 and 12. A solitary albuminous gland in the ninth segment. The free secondary perigastric vessels begin in the thirteenth segment, and are all pulsating. The preseptal secondary vessels not branching, the postseptal one branching. Spines not distinctly forked.* Cephalic lobe not filiform.

* Vejdov-ky, System, etc., der Olig chæten, Prague, 1884, pag. 52.

2. Rhynchelmis Hoffm.

One pair receptacles in the eighth segment. A solitary albuminous gland in the ninth segment. The postseptal secondary vessels are simple, the preseptal ones are feathered and branched. Spines are entire. Cephalic lobe filiform.*

3. Sutroa n. gen.

Seminal receptacles consist of several pairs of lobes, entire or forked, which all open in the so-called albuminous gland in the eighth segment. A solitary albuminous gland in the eighth segment. Preseptal and interseptal secondary dorsal vessel are branching and feathered. Postseptal vessels are gastric, not feathered nor branching. Spines simple, not forked. Cephalic lobe filiform.

It will thus be seen that *Sutroa* is nearly allied to the two other genera of the sub-family, the most prominent characteristic being the concentration of the receptacles and their opening into the albuminous gland. But the vascular system also shows some great peculiarities, which will soon be fully described.

As only one species is known of the genus *Sutroa*, the generic and specific characteristics will here necessarily be considered together.

Sutroa rostrata n. gen. et sp

Habitat.—I have found this species only in Mountain Lake, near the Marine Hospital, west of San Francisco, California. It occurs here only on the north shore, just at the mouth of a small spring, which empties into the lake. It lives in the richest mud, between the roots of aquatic plants, probably with the tail vibrating in the water. When captured and set free in the water, the worms swim rapidly through a peculiar wavy motion of the body, showing to advantage its really magnificent iridescent colors, found to the same degree in no other fresh water annelide. The color of the body is very similar to that of *Rhynchelmis limosella*, a lively fleshy red.

The worm appears to be quite rare, as I did not succeed in getting over a dozen worms during each excursion. It also seems quite restricted to a certain part of the lake, where it lives in the rich mud at the margin of the bank. On the south, east or west ends of the lake I have looked for it in vain.

The egg capsule or cocoons of *Sutroa* are in size nearly similar to those of *Rhynchelmis*, but in shape different. They can nearest be compared to the hanging nests of some birds—small, bag-shaped bodies, with a flat, somewhat concave top—suspended by a long semicircular membrane. Figure 15 gives an enlarged repre-

* Vejdovsky, l. c., pag. 52.

sentation of the same. I generally found three eggs or young worms in the capsule.

The worms appear fully developed in July and August, at which time I found mature specimens. In May only immature ones were found, but as some of those were quite small it is likely that the worms remain mature for a long period, and that perhaps the proper breeding season is during the winter months.

In *size* and *form Sutroa rostrata* much resembles *Rhynchelmis limosella*, Hoffm. Mature specimen reach a length of three inches and a width of one-eighth of an inch, but generally are considerably smaller. The *form* is also similar to that of the above worm. The body is round or quadilateral; in many specimens the sides are even concave (Fig. 3). The posterior part of the body is again very much flattened out, quite transparent, and so brittle that care is necessary to get any entire specimen.

The anterior part of the worm, or the cephalic lobe proper, is elongated and filiform, its length exceeding the width of the body. This characteristic is also found in *Rhynchelmis limosella*, and indeed so similar are the two worms exteriorly that one may easily be mistaken for the other. Fig. 1 represents a *Sutroa*, nat. size; Fig. 2, the anterior portion of the body; and Fig. 3, a transverse section of a quadilateral specimen.

Vascular System.—The dorsal vessel (Figs. 4 and 5, v. d.) is pulsating. The ventral vessel (Fig. 4, v. v.) is not pulsating. In the figures the pulsating vessel is represented red, the non-pulsating one as blue. The ventral and dorsal primary vessels are connected in the cephalic lobe, where at the apex one vessel connects directly with the other (Fig. 4, I). Between this cephalic plexus and segment XIII no direct connection exists between the two primary vessels. But from segment XIII toward the posterior end of the body, we find in every one a secondary gastric vessel which undoubtedly connects the dorsal and ventral primary trunks.

The *dorsal* primary vessel (Figs. 4 and 5, d. v.) is entire, not forked, as is the case in the other genera of *Lumbriculina*. In every segment it emits secondary vessels, which are of two kinds, *gastric* and *perigastric*. The perigastric vessels occur in all the segments of the body; the gastric vessels only in the posterior, beginning with segment VIII.

In each of the six anterior segments we find only one pair of perigastric vessels, but each vessel shows a distinct forking, less so in segment I, but more dis-

tinct in the others. In segment VI the forking is so deep that it nearly divides the vessel in two (Fig. 4, I to VI). In segment VII the forking is perfect, and from that toward the end of the body we find in every segment two distinct pairs of perigastric vessels. Each of these vessels again are forked at the apex, and feathered—that is, besides the forking at the apex, it emits two pairs of side branches. All these secondary perigastric vessels end blindly in the perigastric cavity and do not connect directly with the ventral vessel (Fig. 5).

The *ventral vessel* is not pulsating. It is forked in segment VIII, the forks again uniting with the *dorsal vessel* in the *cephalic lobe* (Fig. 4). A similar forking of the ventral vessel is known in the other genera of *Lumbriculidæ*. The two forks of the dorsal vessel are again connected by secondary perigastric vessels (Fig. 4, v. pr. v.), which, however, in no way connect with the dorsal vessel or its secondary perigastric vessels. In *Rhynchelmis limosella* * as well as in *Phreatothrix* † the contrary takes place. Here the secondary ventral vessels connect the ventral forks with the dorsal pulsating vessel. My observations on the transparent *Sutroa* satisfy me positively that my above description is correct, and that the dorsal and ventral vessels are not united in those segments. The blood in all the vessels is lively yellowish-red.

The *alimentary canal* is extremely simple, consisting of a simple duct. In the twelve anterior segments this duct is narrow and quite pellucid, but in the thirteenth segment it is considerably enlarged and continues so toward the posterior part of the body. In the same segment we first meet with gastric vessels.

The *nervous system* resembles that of *Rhynchelmis*. The two ventral nerve cords are, as in *Eclipidrilus*, connected by numerous anastomosing commissures. The *cephalic ganglion* is rather long and narrow. No lateral nerves project from the ventral nerve cord.

Generative System.—The sexual organs are of two kinds—*generative* and *receptive*. The generative include:

Testes, ovaries and *albuminiferous gland.*

The receptive are: *Efferent ducts*, with *atrium* and *seminal vesicle; oviducts* and *receptacles.*

* Vejdovsky: Anatomische studien. *Rhynchelmis*, Zeitsch, f. w. Zoöl. Bd. XXVII, Taf. XXI, Fig. 1.

† The same. Ueber *Phreatothrix*. Same, Bd. XXVII, Taf. XXXIX, Fig. 2.

The *testes* consist of one pair, situated in segment IX, and attached to the dissepiment between segments VIII and IX. They present small bodies of rather irregular shape (Fig. 14, test.).

The *ovaries* also consist of one pair, situated in segment X, and attached to the dissepiment between segments IX and X. They are somewhat smaller than the testes, and of a more regular form (Fig. 14, ov.).

The *oviducts* consist of one pair of small cup or funnel-shaped organs (Fig. 14, ovd., and Fig. 11). The exterior porus is on the ventral side of the body between segments XI and XII. The interior funnel-shaped part is extremely delicate and translucent. I found the eggs quite frequently in the act of passing out. The oviduct of *Sutroa* differs from that of *Rhynchelmis*, in being somewhat more elongated, with a longer and narrower neck.

The *efferent ducts* are four, and their funnel-shaped interior openings are all found in segment XI, freely projecting from the dissepiment between segments X and XI (Fig. 17). These *efferent ducts* are extremely long, extending through some twenty segments, or from XI to XXX or XXXI. They here enter the atrium, which is similarly elongated, extending from segment X to XXXI. The exterior porus of the atrium is situated very near the center of the ventral side of the line between segments X and XI. This enormous development of the efferent ducts and atrium was previously only found in *Ocnerodrilus*.*

The efferent funnels are comparatively small (Figs. 6, 7 and 14).

* I will here take occasion to correct an error in my former description of this latter genus, for which see "*On the Anatomy of Ocnerodrilus.* Upsala 1878." The organs which I have there described as *seminal receptacles* are undoubtedly nothing but the *atrium*. During a visit to Central America, I found four new species of *Ocnerodrilus*, and a cursory microscopic investigation showed me immediately that seminal receptacles existed in several pairs in some of the anterior segments, which makes it evident that the large bodies which open in the same porus as the efferent ducts must be considered as atrium. In the Californian species which I described as *Ocnerodrilus occidentalis*, these small seminal receptacles were evidently overlooked. Professor Fr. Vejdovsky, in his admirable work, "System der Oligochæten," page 144, takes the same view of these organs, and refers to them correctly as the atrium. I now beg to append a correct diagnosis of the genus *Ocnerodrilus: Dorsal vessel weakly pulsating*, in segments IX and [X; *furnished with two pairs of strongly pulsating hearts.* In the eighth segment it emits two side *branches which continue toward the cephalic lobe.* VENTRAL VESSEL *is not forked, but continues undivided to the buccalic segment. The secondary vessels are of two kinds,* GASTRIC *and* PERIGASTRIC. *The perigastric ones only connect with the ventral vessel. The efferent ducts are not united with the atrium, but both open in the same porus.* SEMINAL RECEPTACLES *occur in pairs in several of the anterior segments.* TESTES—*Two pairs in ninth and tenth segments. Two* OVIDUCTS *in fourteenth segment.* OVARIES—*One pair in twelfth segment.* The genus *Ocnerodrilus* constitutes undoubtedly a distinct family.

The exterior porus of the atrium is in *Sutroa* surrounded by strong muscular swellings, and the atrium itself forms a kind of penis, which probably is to some degree projective. The exterior surface of the atrium is nowhere covered with glands, as is the case in *Rhynchelmis*, but consists of a long, narrow duct of a uniform width (Fig. 6, atr., and Fig. 14, atr.). No basal glands.

The seminal vesicle consists of an enormous sac-like body, entirely filling the twenty segments occupied by the atrium and the efferent ducts. I did not succeed in finding the placé at which it was attached to the atrium.

The most characteristic interior organ, however, is the solitary body, for which I here adopt the name given by Vejdovsky, glandula albuminifera or albuminous gland. I am, however, by no means fully satisfied of the functions of this organ, and its structure seems somewhat different from that of the albuminous glands of *Rhynchelmis* and *Lumbriculus*. The solitary albuminous gland of *Sutroa* opens in the center of the ventral part of the eighth segment (Fig. 14, gl. alb., and Fig. 10). It has the shape of a globulous body, connecting by a narrow neck with the body wall and opening through an external large porus. But the histological construction of this gland is quite different from the gland described by Vejdovsky in *Lumbriculus* * and in *Rhynchelmis*.†

In the latter two genera this organ is distinctly glandular, but in *Sutroa* it is of nearly the same construction as the receptacles, being covered by smooth epithelium, under which are found numerous long and narrow cells (Fig. 10). I have, however, no reason to doubt but that these organs are analogous in all the three genera.

The *receptacles* in *Sutroa* consist of three pairs. In *Rhynchelmis* and *Lumbriculus* we find the receptacles open each in a separate porus; in *Sutroa*, however, there exists the great anomaly that all the six seminal receptacles open into the narrow neck of the above described solitary gland (Fig. 10, re. sem.). These receptacles consist of long narrow sacks, containing fully developed spermatozoa (Fig. 8). Generally there are three pairs of receptacles, but in some specimens I found three receptacles on one side and only two on the other. Sometimes the interior end of a receptacle is forked; generally, however, they are entire. That these elongated bodies are real receptacles is proved by their being full of spermatozoa fully devel-

* Vejdovsky, System der Oligochæten. Taf. XII, 16. g. alb.

† Same. An. stud. Rhynchelmis. Taf. XXIII, Fig. 17.

oped. In the albuminous gland, however, I have searched in vain for any, though I must confess the number of specimens at my disposal has been very small.

The *segmental organs* are found in all the segments posterior to XII. They consist of long slender organs, the body of which is destitute of any glandular appendices or cells similar to those found in *Rhynchelmis*. The interior opening of the organ is surrounded by brown glands, behind which there is a larger head-like enlargement of similar structure to the duct proper (Fig. 12).

The *spines* are eight in every segment and occur in four pairs. They are slightly S-shaped, entire, not forked (Fig. 13).

EXPLANATION OF THE FIGURES.

PLATE I.

Fig. 1. *Sutroa rostrata*, natural size.

Fig. 2. Front part of the worm, with the cephalic lobe, showing its filiform elongation.

Fig. 3. Transverse section of the body of a quadrilateral specimen.

Fig. 4. The front part of the worm, showing the vascular or circulatory system. The dorsal vessel is represented red; the ventral vessel, blue.

d. pr. v.: dorsal perigastric vessel.
v. pr. v.: ventral perigastric vessel.

Fig. 5. The twelfth to fourteenth segments, showing the vascular system in those segments.

ac.: alimentary canal.
dv.: dorsal vessel.
d. pr. v.: dorsal perigastric vessel.
d. gr. v.: dorsal gastric vessel.

Fig. 6. The efferent ducts and atrium.

ps.: penis.
eff. d.: efferent ducts.
atr.: atrium.

Fig. 7. Efferent funnel more magnified and seen in different aspect.

PLATE II.

Fig. 8. Ventral nerve trunk and cephalic ganglion.

Fig. 9. Seminal receptacles and albuminous gland.
re. sem.: seminal receptacles.
gl. alb.: albuminous gland.

Fig. 10. Interior extremity of one of the receptacles, showing the spermatozoa accumulated in the same.

Fig. 11. One of the oviducts, with eggs in the act of descending.

Fig. 12. The interior extremity of one of the segmental organs.

Fig. 13. One pair of spines.

Fig. 14. Interior view of the ventral part of the worm.
gl. alb.: albuminous gland.
re. sem.: seminal receptacles.
test.: testes.
ov.: ovaries.
ovd.: oviducts.
atr.: atrium.
eff. d.: efferent ducts.

Fig. 15. One of the egg capsules or cocoons. In the interior are seen three young worms, magnified about five times.

The Roman numerals everywhere indicate the segments. In numbering the same I have everywhere in this paper referred to the first segment as segment I, thus following Vejdovsky and others. In former papers I have always referred to the first setigerous segment as segment 1, and believe yet this way to be the least confusing. But as uniformity in numerating the segments is highly desirable, and as every investigator seems to have his pet way, leading to endless misunderstanding, I shall for the future accept the system used in this paper, hoping all other investigators will do the same.

Fig 8.
XI
XII

On some Ancient Sculptures from the Pacific Slope of Guatemala.

By Gustav Eisen.

During my visit to Guatemala, Honduras and Salvador, in 1882, I made the archæological remains of the Mayas and the Aztecs in those countries my particular study. These researches were embodied in a paper presented to the Smithsonian Institute in 1883. This paper treated principally of the ruins of Copán and Quirigua, in Honduras and Guatemala. Through an unfortunate mishap a portion of this paper was lost in transferring from the Smithsonian Institute to the Bureau of Ethnology in Washington, D. C. This delayed the printing of the same four years. In the meantime Mr. Alfred Maudslay, of London, carried on extensive excavations in both the above places. His researches being so much more extensive than my own, and now soon to be published, will in a measure supersede them, and make their publication less desirable or entirely superfluous.

The following paper contains only those portions of my former researches which refer to parts not visited by Mr. Maudslay. The historical traditions of these localities are entirely lost, and instead of indulging in vague and at present highly unsatisfactory speculations about possible relations, life, characteristics, etc., of the people who produced the sculptures found there, I shall mainly confine myself to describing what I have seen, leaving future explorers, with more material, to generalize and speculate upon the, of late, rather fashionable myths of Tlalocs, Quetzalcoatle, Toltecs, etc.; but this much I will say in regard to the people who originated these sculptures—that they were, undoubtedly, of Aztec origin; the worn gylphs yet to be distinguished show similarity to Aztec and not to Maya writings.

El Portál, Pantaleón, Los Tarros, Santa Rita, Santa Lucia Cotzumalguapa and Aguná.

In the above named places as well as in many others along the Pacific Coast of Guatemala, from the very slope of the volcanoes to the shores of the Pacific Ocean, are found numerous traces of ancient civilization. So numerous seems the population of the country to have once been that there is now scarcely a single farm upon which is not found ruins or relics of some kind. But the monuments

on this coast are of an entirely different type from those of Guirigua and Copán, and it is perfectly evident that they were constructed by entirely different people, who resembled each other, neither in regard to physiognomy, dress or ornaments, nor in regard to the glyphs used for expressing their ideas, etc. The monuments of the Pacific Coast are of several kinds, viz.:

1. Larger or smaller hills or mounds made of soil, or soil and rough or rounded stones. Generally three or four of these mounds are grouped together forming between them a kind of inclosed courtyard. Some hills are several thousand feet in length and some twenty feet high; others only fifty to sixty feet long, the height being the same as the former.

2. Smaller mounds, in which are seen a low foundation of rough stone, not fixed with mortar.

3. Bridges and aqueducts made of cut stones, beautifully laid without mortar, and wonderfully withstanding the destruction of time. Such are found around Santa Lucia and Los Tarros.

4. Sculptured stones, representing heads of men or animals, in all grades of skillful manufacture, some most beautifully made and designed, such as the large head from Los Tarros; others again very primitive, like those of Aguná.

5. Hollow stones or fonts, richly ornamented, used either for baptism or for sacrifices.

6. Sculptures in low relief, representing mythological or historical events, or records of some kind.

7. Pottery of different kinds, such as dishes, vases, and musical instruments with heads of beasts and man; also smaller idols of burnt clay. This pottery is evidently from different epochs. The finest made wares are found near or on the surface, while the poorest kinds are found deeper in the ground, as far down as nine feet. I have this assertion from several gentlemen owning farms on the coast, especially from Don Joaquin Durand, who has repeatedly found ancient pottery at different depths on his farm — "Sapote," at the base of Volcan de Fuego. In our present time no such wares are worked by the Indians anywhere on this coast, nor can the present crockery of the Guatemala Indians, in skillful workmanship or even in the fineness of the clay used, compare with the ancient pottery found in the ground. Only in the wild and entirely unconquered country of the Lacandres, between Guatemala and Yucatan, have the natives to this day preserved the art of finer pottery making. Edward Rockstroh, who made an expedition to this country

a few years ago, and who succeeded in penetrating far enough in the same to visit several hamlets or ranchos, brought from there several idols well made. The general form was a small dish, furnished at one side with a large head. These objects were both idols and sacrificiary places. In the hollow of the pots was placed incense or libation, and the god for which it was destined, was represented by the head attached to the dish. These heads, or faces, were in many regards exactly similar to those found on the Pacific Coast, and bore also a remarkable resemblance to the faces and heads of the Peruvian pottery. The ground color of the pots was also a dark grayish-black, while the pottery from the Pacific Coast, as well as that from Copán and other places of Maya origin, is yellowish-red, and sometimes ornamented with painted glyphs.

In the "Instituto Nacional" of Guatemala, is a fine and interesting collection of pottery from different places of that Republic; but like everything else in that country, it is in a deplorable state, the catalogue being missing, so that the numerals on the different objects cannot be referred to. Nobody has charge of the "museum," or takes any interest in the same. Mixed with the ancient Indian pottery are some Egyptian idols, as well as pieces of unburnt European pottery, most likely believed by the "authorities," to be of the same origin, and having as much or as little interest.

The sculptured stone heads found all over the coast are all furnished with a large conical projection, as can be seen by referring to the different figures appended. This projection was evidently formed for insertion into the adobe or stone walls of the respective temples, and served to keep the objects in position. They have no connection with phallic symbols or worship. Most likely, when the sculptures were in their original places, these projections were not seen, but were entirely hidden in the walls.

In producing drawings of different sculptnres, my intention was not, neither did my time permit me, to again draw stones which had once been drawn and photographed by former explorers. My intention was only to bring to notice what was not previously known, and thus, as much as I could, complete the work so ably begun by others. This especially refers to the sculptures of Santa Lucia, where Dr. Habel and Prof. Bastian have already done considerable work. In regard to the sculptures of the other places here referred to, I believe so far no accounts of the same have been published, and I drew there as many as I could find, within the limited time at my disposal.

EL PORTÁL.

The above is the name of a coffee plantation and farm, owned by Don Manuel Herrera, at the time of my visit Minister of Agriculture in the Government of Guatemala. The plantation is situated only a few minutes' walk from "Antigua," the old capital of Guatemala. The monuments of this place comprise a large *natural* hill or mound several hundred feet high, and perhaps five hundred feet in diameter. The top is covered by three smaller mounds, artificially made. From the top of one of these smaller mounds, and down the steep south side of the larger one, is seen the very much ruined remains of a roughly made stairway, the stones once composing its steps having neither been cut nor well fitted. Along the lower part of this stairway, and also between the three small mounds at its top, were found all the sculptures known from this place. At the base of the stairway is yet seen a large basalt block, in which can barely be made out the figure in low relief of a large tiger of natural size. A little higher up are seen several very rough heads of animals, as well as a deer head, but they can hardly be called sculptures, the original stones having somewhat resembled heads, and only been helped by the artist by the addition of a line for the mouth or a hollow for the eye. All the better sculptures were some time since removed to the near dwelling-house and here sheltered from rain and destruction; Señor Herrera being one of the few native gentleman in Guatemala who takes interest in the ancient relics of the country. The following sculptures are all which are at present known from this place. The numerals refer to the figures appended only where "Fig." is put in front of them.

FIGURE 1. Large block of basalt with the upper surface covered with a tiger in bas-relief. The tongue is stretched out, and on the same is seen perched a bird with long bill, very similar to an *Alcedo*. Size $5\frac{1}{2}$ by $3\frac{1}{2}$ feet.

FIGS. 2 and 3. Head of a male personage—Fig. 2 representing the same seen from the side, and Fig. 3 from the front. The face is serene and well made, furnished with a beard. On the head is seen a kind of helmet, the original of which was perhaps made of wood. In this helmet is seen a smaller face, and on the side of it the two arms bent upward. The back is furnished with a projection. Size of Fig. 2, 19 inches long by $14\frac{1}{2}$ inches high. Size of Fig. 3, $14\frac{1}{2}$ inches high by $8\frac{1}{2}$ wide.

FIG. 4. Head of some animal, perhaps a snake, seen from the front. Rectangular posterior projection. Size, $11\frac{1}{2}$ inches high by 13 inches wide. Roughly made sculpture.

FIG. 5. Head of another similar animal, but seen from the side. The upper surface of the skull has inscribed upon it two C's, a similar ornament often being found in snakes. Size, 19 inches long by 11½ inches high.

FIGS. 6 and 7. Head of some fictitious animal, perhaps modeled after a tiger. Fig. 6 represents it seen from the front. Size, 13¾ inches broad by 19 inches high. Fig. 7 is the same seen from the side. Size, 25½ inches long by 19 inches high.

FIG. 8. Head of a fictitious animal. Behind is seen the remains of a hollow, perhaps a font. Front view. Size, 13 inches broad by 8½ inches high.

SANTA RITA OR CARMEN.

This place is situated between Santa Lucia Cotzamalguapa and Pantaleón. So far only one sculpture is found in this place, represented in Figs. 9 and 10. The lower part of the skull is wanting. Fig. 9 represents it seen from the front and Fig. 10 from the side. This skull, as well as the heads from Pantaleón, have the angle of the face very large. The sculpture is at present at Pantaleón.

PANTALEÓN.

This place is situated one league southeast of San Lucia, and belongs at present to Don Manuel Herrera. The sculptures found on this place are removed from their original site, and now to be seen in a yard behind the main dwelling-house. Originally, however, they were found on the ground between four small mounds, enclosing between them a kind of courtyard, having the entrance on the south side. The sculptures consist only of heads of male and female personages, originally six in number, but one of them has been taken to Berlin, Germany, by Dr. Bastian. I am, however, not aware of it having been described. The remaining sculptures are all very well made, cut out of a dark basalt from Volcan de Fuego, some thirty miles distant. The rocks, however, were most likely found on the place, as rounded stones of similar nature are in some places abundant on the ground. All the sculptures are furnished with a large posterior projection for insertion in the wall.

Figs. 11 and 12. Head of an old woman, the face with very deep wrinkles all over. Remarkable in all these heads is the head-dress, which is just the opposite of the head-dresses worn by the idols of Quirigua and Copán. Instead of being enormously large, it is extremely small, and evidently used more as

an ornament than as a protection. In this head it consists of a small central bow, from the sides of which extend two wings of feathers. The whole seems attached to some kind of frame, on each side of which hangs down two smaller ribbons and one larger one. Fig. 12 shows this head-dress as seen from above.

Fig. 13. A head of a young woman, of handsome features. The hair is abundant and seems to hang below the ears. These, as in all the rest of the sculptures, are unnaturally large, most likely enlarged by some process. The head-dress is in the form of a crown, or at least ornamented as such. The figure shows the head from the front.

Figs. 14, 15 and 16. Head of a very old woman, seen respectively from the side, front and from above. The hair is laid in thick tresses and covered by an exceedingly small hat. The ears are enormously large, their lower lobes extending and projecting forward. The most remarkable things to be seen in this face are the eyeballs, which are hanging down outside on the cheeks. The upper lip is small, while the lower one is very large and projecting. The nose is broken, but enough is left to show its original large size.

Figs. 17, 18 and 19. Head of an old woman, seen respectively from the side, front and from above. The hair is ornamentally laid and covered by a very small hat; by the same is seen a bow. The right eyeball is hanging on the cheek. The nose is large and aquiline, not broken. Below the face is seen a kind of collar extending from ear to ear.

Figs. 20 and 21. Head of an old man, seen from the side and from above. The nose is partially broken. Forehead and face deeply wrinkled. Head covered by a cloth and a very small hat. The ears have large ornaments.

The size of these five sculptures is nearly the same. Length, 32 inches, hight 24, and width 16 inches.

What these heads represent will at present remain only a conjecture. In Yucatan criminals were punished by the extraction of their eyes, but I am doubtful about these heads representing criminals, as they then would most likely not have been ornamented, as it seems, in so very fashionable a way. Besides, the expressions of their faces are always noble and serene, which would not have been the case if a criminal had been represented. Even those having their eyes extracted show no signs of pain whatever. The faces represent evidently very old people, at least judging by the very deep wrinkles which cover their foreheads and cheeks. May

not these heads represent saints, some of whom had martyred themselves and whose images had since been set up for adoration?

I was informed that similar sculptures are not uncommon in the neighborhood, but the above ones are said to be much superior in execution. The following localities are said to contain similar sculptures: Santa Ana or Mistan, about nine leagues south of Pantaleón; Gomera, about ten leagues south of Pantaleón. Also in the vicinity of Santa Lucia six heads were to be seen, which were said to exhibit the peculiarity of having animals and bars projecting from the mouths. Even in a place north of Pantaleón is said to be a large head more than six feet high, in similar style with those removed to the house and described above.

LOS TARROS.

This place is situated northwest of Pantaleón a few leagues distant. I did not visit the place, the time and weather not permitting it. One of the two sculptures found on this place is removed to Pantaleón, and arrangements have already been made to remove the other. Both sculptures are said to be nearly exactly alike, the one remaining in its place only being a little larger. Originally both sculptures stood on a plain facing each other, and 20 to 30 yards apart. Fig. 22 represents the smaller of the sculptures, seen from the front, and Fig. 23 the same seen from the side. The size is: hight, 68 inches; width, 44 inches; thickness, 24 inches. The sculpture represents the bust of some prominent male personage, standing out in bold relief from a stone slab, slightly ornamented. Above the slab is seen the head of a large fictitious animal, with a large hole perforating the base of the same. The face of the personage is most serene and noble, and expresses great kindness. The head-dress is very large, a kind of turban, very much inflated, in front furnished with an ornamental projection, in which is seen a face lying on the side, and in front of this a smaller ornament like a gem. Behind the face are seen three leaves, and behind them, extending towards the margin of the stone slab on each side, a bunch of very long and rather narrow leaves, with a nervation similar to that of *Melastoma*. The ears of the personage are large, furnished with ornaments, in the middle of which is seen a hanging boss. On the breast is an ornament with five small holes in the margin, and a human face in the center. The fantastic head, hanging ominously above the slab, is of a wonderful effect, and the perforation of its side breaks the heaviness of the sculpture. In elegance of design and in workmanship this stone is undoubtedly one of the very finest ever found in Central America; and it is much to be regretted that it is not protected from the

injurious influences of the tropical rains and sun. Originally the stone had a large posterior projection, but this was cut off so as to facilitate transportation.

SANTA LUCIA COTZUMALGUAPA.

The sculptures from this place are pretty well known through the works of Dr. Habel* and Dr. Bastian.** Some of the slabs have been removed to Berlin, but the largest part is yet to been seen at the original place, but exposed to rain and other bad treatment. Many of the sculptures are so faint that it is necessary to draw up the lines with chalk before any complete idea can be had of the same.

The sculptures, when originally found, were covered by soil, the same being thrown up into hills or mounds. At present the whole country around is covered with these mounds of smaller and larger size, and as only a few of them have been opened, it is not unlikely that the number of sculptures will be considerably increased when a thorough search has been made. The way the sculptures were, or are, hidden in the ground, is very peculiar. Some of them are lying down flat on or near the top of the mound; others are standing upright, but covered with soil up to their very tops. It is evident that the soil has not accumulated slowly from decayed vegetation, etc., but it seems rather as if the sculptures have once purposely been covered up, to be hidden, perhaps, at the approach of some enemy. At the time of the Spanish conquest the whole of the Pacific Slope was here densely populated, especially around and near Escuintla, from which Santa Lucia is only distant some thirty miles.

Through the kindness of Mr. Edward Rockstroh, I came into posession of some lead pencil and ink drawings of sculptures from Santa Lucia, made by the late Dr. Carl Herman Berendt, and received also permission to publish the same. One of these drawings I had already a copy of, made by myself at Santa Lucia; but as my drawing was wanting in the lower part—this part at my visit being covered with soil—I prefer to give the drawing of Dr. Berendt as being more perfect. As this as well as his other drawings, were not exactly in a state to be lithographed, very often having corrections of minor details on the margins, I recopied them, inserting the corrections, etc. It is to be regretted that no notes as to size accompanied the drawings, and only meager ones as to localities.

*S. Habel.—The Sculptures of Santa Lucia Cotzumalguapa, etc. Smithsonian Contribution to Knowledge. 269. Apr. 1879.

**The work of Dr. Bastian, in quarto, 3 plates, printed in Berlin? has no title, at least not the copy that I have seen.

Fig. 24. Large stone slab, about nine feet high by six wide. The sculpture represents some religious ceremony. Two men are carrying between each other a standard, and appear to deliver the same to a third person. The standard is ornamented by several appendices, one being especially large and circular, and having in its midst the face of a monkey. In the margin of the stone are seen several round rings with glyphs or signs, but all are so effaced that no correct delineation is possible. This slab is yet standing upright in a mound, and was originally entirely covered with earth, but at present the larger part of the face is uncovered.

Fig. 25. Stone slab found in the grounds of Virgilio Pais, on the plain of Quayabo, near Santa Lucia. Drawing made after a sketch by Dr. C. H. Berendt. The central figure represents a chief richly dressed, with a girdle round the waist, one extremity of the bow ends in a snake-head extending toward the woman standing in front. One of the legs of the chief is ornamented; the other bare. The head-dress, behind which is seen a large bird, perhaps the common black vulture of Central America, is large and ornamented with many feathers. In front of the man stands a woman, evidently emaciated, as her ribs are plainly seen. She appears entirely naked, except a girdle round the loins. Her hair is elegantly dressed and tied with ribbons. Behind her is seen an evil spirit, or other mythical personage, with claws on hands and feet, and a very pronounced male member. The chief has his mouth covered with a bandage.

Fig. 26. Original from the grounds of Virgilio Pais; the drawing after a sketch by Dr. C. H. Berendt. Represents a sepulchral tablet, on which are seen the portraits of perhaps man and wife, their different head-dresses, etc., indicating decidedly their different sexes. From the mouths of the respective portraits extend as usual curved figures with notes or nodes. A similar speech writing is found in all Mexican manuscripts, as can be seen by a reference to Lord Kingsborough's Mexican Antiquities, for instance, Tom. III, p. 26. This writing is entirely unknown in Maya sculptures and manuscripts, but is seen on some sculptures at Chichen, Yucatan.

Fig. 27. From the same locality, and after a sketch by Dr. C. H. Berendt. A stone tablet, most likely, like the former one, a sepulchral tablet, having in its center a forced deadhead, with outstretched tongue. Above the same are seen two crossed bars, perhaps meant to represent two crossed bones.

Figs. 28 and 29. The two sides of a sacrificial font or altar. The front is twenty-four inches high, ornamented with a face like that of a dead man. The ears

are enormously large. Above is seen a cavity in the margin, in which perhaps the victims were made to place their heads at decapitation. The hollow posterior cavity of the font, used for the reception of the cut-off head, is twenty-one inches broad by twenty inches deep. Locality: Xata. (After a drawing by Dr. Berendt.)

AGUNÁ.

Situated some twenty miles northwest of Santa Lucia and owned by Dr. Guillermo Rodiguez of Guatemala. The whole place is covered by artificial mounds. About nine miles south of the main dwelling-house are seen, among other hills, three smaller ones made of soil and rough stones. These mounds, perhaps fifteen feet high and forty feet long, are placed so as to form a small courtyard. In this courtyard were found the sculptures here represented, viz.:

Figs. 30 and 31. A stone sculptured as a head, with a posterior projection for insertion in a wall. The sculpture is represented both from the side and from the front.

Figs. 32 and 33. A similar stone, with a forced deadhead in front and several ornaments. In execution these heads do not compare with the sculptures of Pantaleón, being very much inferior, both in design and workmanship. Their size is about four feet long by two high.

EXPLANATION OF THE FIGURES.

FROM EL PORTÁL.

Fig. 1. Sculptured tiger in low relief. The tongue is outstretched and on the same is sitting a bird.
2. Head of male personage, seen from the side.
3. Head of the same, seen from the front.
4. Head of fictitious animal, front view.
5. Head of an animal similar in size and shape to the above, but side view.
6. Head of a fictitious animal, seen from the front.
7. The same, side view.
8. Fictitious animal or deadhead, remains of a font, front view.

FROM SANTA RITA OR CARMEN.

9. Sculptured deadhead of man, seen from the front.
10. The same, side view.

FROM PANTALEÓN.

11. Sculptured head of woman, side view.
12. The former, seen from above, to show the head-dress.
13. Sculptured head of woman, front view.
14. Sculptured head of woman, side view.
15. The same, front view.
16. The same, seen from above, to show the head-dress.
17. Sculptured head of woman, seen from the side.
18. The same, front view.
19. The same, seen from above, to show the head-dress.
20. Sculptured head of woman, seen from the side.
21. The same, seen from above, to show the head-dress.

FROM LOS TARROS.

22. Large, sculptured stone slab, in the middle the bust of a male personage; above, a fictitious animal's head.
23. The same, seen from the side.

FROM SANTA LUCIA COTZUMALGUAPA.

24. Large, sculptured stone slab, in very low relief, representing some religious or civil ceremony. Two male personages are seen carrying a standard, and presenting it to a third.
25. A chief or other personage, in rich dress, and head-dress or helmet with plumes. Behind the same is seen a bird; in front, a female figure, and behind her a fictitious personage. The sculpture is in low relief.
26. Smaller sculptured slab, perhaps originally the cover of a tomb or made in memory of the two personages whose portraits are seen on the stone.
27. Sepulchral stone slab; in center the image of a deadhead surrounded by many ornaments.
28. Sacrificial font, seen from the side. The font has a shield with a sculptured face.
29. The same as above, front view. The small cavity in the top was evidently used for holding the victim's neck; the font behind receiving the head when decapitated.

FROM AGUNÁ.

30. Sculptured stone head, with posterior projection; seen from the side.
31. The same; front view.
32. Sculptured stone head—a forced deadhead, with ornaments; front view.
33. The same; side view.

Sculptures of El Portál, Guatemala

Gustav Eisen, del.
9/1892.

Artg. Britton & Rey, S. F.

GUSTAV EISEN, del.
9/1882.

ARTO. HUFTON & REY. S.F.

Sculptures of Portál, Antiqua;
and Santa Rita or Carmen, Pantaleón, Guatemala.

GUSTAV EISEN, del.
9/1882.

ARTO. BRITTON & REY, S.F.

Sculptures of

GUSTAV EISEN, del.
9/1882.

ARTO. BRITTON & REY. S F

Sculptures of Pantaleón, Guatemala.

GUSTAV EISEN, del.

ARTO. BRITTON & REY. S.F.

Sculptures of Los Tarros, Pantaleón, Guatemala.

GUSTAV EISEN, in part, after sketch by Dr. Berendt.

4 1882.

ARTO. BRITTON & REY, S.F.

Sculptures of Santa Lucia Cotzumalguapa, Guatemala.

GUSTAV EISEN, after sketch by Dr. Berendt.
8/1882.

ARTD. BRITTON & REV. S.F.

GUSTAV EISEN, after sketch by Dr. Berendt.

9/1882.

ASTO. LITH. & ENG. S.F.

Sculpture of Santa Lucia Cotzumalguapa, Guatemala.

Gustav Eisen, del.
4/1882.

ARTO. BRITTON & REY. S F

Sculptures of Aguná, Guatemala.

ON CALIFORNIA EUDRILIDÆ.

BY GUSTAV EISEN.

The California Oligochæts, to be described below, are all related to the well-known genera Microscolex, Pontodrilus, Plutellus, etc., referred by Benham, Rosa and others to the general family of Eudrilidæ, and by Beddard to his family Cryptodrilidæ. I will not here discuss the relative merits of the respective families, as the number of species belonging to them is hardly sufficient to enable us to as yet come to any definite conclusion. For the present, at least, I retain these genera in the family of Eudrilidæ. But I must concede that this family, as defined by the above investigators, contains two distinct main types—one represented by Eudrilus and the other by Microscolex—and a separation in families should be made in reference to them, though I am not prepared to make the separation as wide as Beddard has done. Our California species ally themselves to the Microscolex group, and especially to Microscolex and Plutellus. A species of Pontodrilus was found too late to be included. I believe this family may be conveniently divided into several subfamilies based upon the openings of the spermducts, prostates, penial sacs, as well as upon the location of the nephridio-pores. Our California forms may thus be grouped as follows:

PONTODRILINI.

The eight setæ are separate though in four couples on every somite.
Clitellum complete.
Male pore in somite xviii.
Nephridia—mega-nephridia only—commence posteriorly to somite xiii; the pores are in line with setæ 2′, not alternating in position.
The prostate receives the spermduct previous to its entering the male pore.
No gizzard, no typhlosole, no subneural vessel. PONTODRILUS E. P., 1881.
PHOTODRILUS Girard, 1887.

MICROSCOLECINI.

Eight setæ separate in four couples; the setæ of the inner couples not always parallel.
Clitellum complete.
Male pore in somite xvii.
The prostate receives the spermduct previous to its entering the male pore; or opens separately in the same somite.
The nephridia commence anterior to somite v; the nephridia in line with one of the setæ 3 or 4. The first few anterior pores may open in front of a different setæ from the posterior ones.
No gizzard, no typhlosole, no subneural vessel. RHODODRILUS Beddard, 1889.
MICROSCOLEX Rosa, 1887.
DELTANIA Eisen, 1893.

PLUTELLINI.

Setæ eight, in couples or equidistant.
Clitellum perfect or imperfect.
Male pores in xviii.
The prostate either receives the spermduct or it opens separately, but in the same pore.
The nephridio-pores show a systematic alternation in position either in front of or outside of the setæ.
A gizzard; a small typhlosole may be present PLUTELLUS Perrier, 1873.
ARGILOPHILUS Eisen, 1893.

The genera related to Microscolex may be arranged as follows:

I. Male pore in somite xviii. Nephridia commences posterior to somite xiii.
PONTODRILUS and PHOTODRILUS, etc.

II. Male pore in somite xvii. Nephridia commences in the anterior somites ii to v.

a. Spermducts open independently of the prostates. RHODODRILUS.
Sp.: *minutus; novæ-zelandiæ.*

b. Spermducts open in the prostate, close to the body-wall.

1. The setæ of the inner couples (setæ 1 and 2) in the vicinity of the clitellum are parallel with each other and do not converge toward any one of the genital pores. Nephridia commence in ii to iv. MICROSCOLEX.
Sp.: *modestus; algeriensis.*

2. The setæ of the inner couples (setæ 1 and 2) in the vicinity of the clitellum converge toward one or both of the genital pores. Nephridia commence in somite ii to v. DELTANIA.
Sp.: *elegans; Troyeri; Benhami; Poultoni; dubia.*

DELTANIA.

Deltania Eisen, Zoe, iv, 250, October, 1893.

Prostomium encroaches on somite i. Eight setæ in four couples ventral and lateral, beginning in somite ii. The setæ of the inner couples in the genital region converging toward the male pore. The setæ of the outer couples are further apart than those of the inner couples. There are a buccal cavity, pharynx, œsophagus and sacculated intestine, but no gizzard, thyphlosole, or œsophageal pouches. Clitellum, which is perfect, contains three large somites and two outside smaller ones, extending from xiii to xvii. No dorsal grooves. Testes in x and xi, free. Sperm-sacs present, free. Spermatheca present or absent, variable in position and shape. Ovary one pair in xiii. Oviduct one pair in xiv. Two pair of ciliated rosettes in x and xi. Spermducts open in xvii together with a large prostate which is placed parallel to the segmental grooves. The spermducts join the muscular part of the prostate at the point where it enters the body-wall. The glandular part of the prostate consists of two layers of cells. Penial setæ open in the same duct as the prostate.

The dorsal vessel with three pair of lateral hearts in x, xi and xii. No subneural vessel. Only very few blood vessels on the nephridia.

Nephridia are of two slightly different kinds. Those in the first few anterior somites, commencing in somite ii, open in front of and a little interior to the 4th seta, while those posterior to the former open in front of and a little lateral to the 3d seta. The nephridia begin generally in ii, rarely in v. All nephridia furnished with a large terminal bladder which in the posterior nephridia develop a cœcal prolongation.

Small, transparent-glassy, more or less colorless worms with orange colored clitellum, and living in moist, especially sandy soil.

Systematic position. Under the genus Deltania I group all species which would otherwise be referred to Microscolex Rosa, but which agree in having a deltoid arrangement of the ventral setæ surrounding the generative and especially the male pores. With this character I believe a closer investigation of the species of Microscolex will join others, principally in regard to the nephridia which have not been sufficiently studied, probably on account of the scarcity of specimens for research.

Among species which must be referred to the genus besides those described

below are *Microscolex dubius* of Rosa and *Eudrilus dubius* of Fletcher. I will first refer to the latter. Fletcher's description is sufficiently minute to allow us with certainty to refer it to the genus, but the details are wanting to such an extent, that it is difficult to understand its further relationship. There are three points in the description which are of special interest.

1. Absence of spermathecæ.
2. The beginning of the nephridia in v.
3. The junction of the spermduct and the prostate half-way between the glandular part and the body-wall.

As to the first of these the spermathecæ may be really wanting or it may have a substitute similar to the one found in *Deltania elegans* as described below. At any rate this character brings the species *Eudrilus dubius* close to *Deltania elegans* as well as to Beddard's *Microscolex Poultoni*.

The beginning of the nephridia in somite v brings *E. dubius* close to Beddard's species but separates it distinctly from *Deltania elegans* in which the nephridia commence in ii, as will be shown below.

The third character requires to be reaffirmed and described more in detail. The joining of the spermduct and the prostate is always of the utmost importance and interest and a mere general statement will not suffice for properly characterizing a species, especially when the group is little known.

Rosa at first considered *E. dubius* to be identical with his *Microscolex modestus*, but a later investigation of new material convinced him of the distinct character of the species and he then describes both as two different species of Microscolex. It must therefore be considered certain that the deltoid arrangement of the ventral setæ does not occur in *Microscolex modestus*. In regard to the respective species of *E. dubius* and *M. dubius* described by Rosa and Fletcher, I am not fully persuaded that both actually belong to the same species, and I believe that nothing short of an actual comparison of the specimens can decide if they do so.

Beddard has at two different times described species of the genus Microscolex, but which differ from each other in several important points. *Microscolex novæ-zelandiæ* resembles the old genus Rhododrilus in the independent opening of the spermduct. Instead of referring the above species to Microscolex, and merge Rhododrilus in the latter genus, I consider it more proper and convenient to retain Rhododrilus and refer *M. novæ-zelandiæ* to it, as the independent opening of the spermduct appears to me of sufficient importance to be considered a generic character. Another species, *Microscolex algeriensis*, also described by Beddard, can, I believe, best be retained in the genus Microscolex, as it evidently possesses the setæ parallel throughout the ventral side of the clitellum.

Microscolex Poultoni however is probably a true Deltania and Beddard's excellent description leaves no important characters in doubt.

In his description of *Microscolex Poultoni*, Beddard refers especially to the deltoid arrangement of the setæ in the clitellial somites. He says: "From segment

xix backward and from segment xiii forward, the distance between the two ventral setæ of each side gradually increases."

Distribution and habitat. The species of the genus Deltania described below are undoubtedly natives of the Pacific Coast of North America, and more particularly of California. The species are found not only in the Golden Gate Park of San Francisco, where they might have been introduced, but also in localities distant from gardens, and in which no cultivation has ever taken place. Thus I have species from Berkeley, Santa Rosa, Lake Chabot, Mount Diablo, etc. Moreover, since this paper was finished in MS., I have found species of Deltania in localities so far from civilization that there can be no doubt as to the native habitat. I refer to species found in the high mountains of the Cape region (in the vicinity of Cape San Lucas) of Baja California, at an altitude of 4,000 feet, in almost inaccessible localities. A species has also been found in a gulch or river-bed at Ensenada, Baja California, thus proving the extensive territory over which the genus extends. The description of these species must be deferred to another paper.

As regards *Deltania dubia* (?*Eudrilus dubius* Fletcher) and *Deltania Poultoni* (*Microscolex Poultoni*, Beddard) it may be possible that the former, at least, is an introduction from abroad. The locality where the latter is found shows the genus to possess a wide neotropic extension.

While it is thus certain that species of Deltania are natives of the new world and the Atlantic islands, and especially of the Pacific Coast of North America and Mexico, the distribution of Microscolex must yet remain undecided. Whether it was imported from the Argentine Republic to the Mediterranean region, or vice versa, must remain an open question, though the finding of two species in the Mediterranean countries seems to point to the probability of that region being its real habitat.

Species. Of the genus Deltania, California now possesses at least three species with the very great probability of a discovery of new species, as soon as a wider area may have been explored. All the species appear very sensitive to dryness and heat and disappear with the first warm and dry weather, hence the difficulty of finding them except at their proper season which appears to be limited to February to April in the vicinity of San Francisco. The species in Baja California were found in September and October.

Deltania elegans.

Figs. 1–20, 49–58.

Deltania elegans Eisen, Zoe, iv, 248, October, 1893.

Size about 2 to 4 inches by from $\frac{1}{16}$ to $\frac{1}{8}$ inch wide. Septal glands very small, the posterior one the smallest. Spermathecæ very pellucid, minute, and irregular in their position both as regards somite and the place in the somite, but generally opening between viii and ix. Sperm-sacs comparatively small, deeply lobed, one pair in xi and

one in xii. Prostate is at the top helix-like folded. Penial papillæ prominent, with two or more penial setæ in each sac.

The worm is very pale, glassy, semi-transparent with reddish-orange clitellum, and with the dorsal vessel showing prominently through the body-wall. It is very delicate, succumbs readily to heat and can only with difficulty be kept alive. It is the largest of the species belonging to this genus as far as known.

Habitat. *Deltania elegans* is so far only found around San Francisco, California, and at Santa Rosa and Mount Diablo, especially under decaying manure in natural hollows in the Golden Gate Park. It is common immediately north of Strawberry Hill in the sandy hollow where rain water collects and keeps the soil sufficiently moist. The worm is not found in the water, but at the water's edge, the water, however, being only temporary during the rainy season. A few specimens also found in Berkeley along the creek. In the locality in Golden Gate Park the worms congregate in large masses, always in the sandy soil. At Santa Rosa and Mount Diablo I found only few specimens, the season being at my visit in May far advanced and the soil was drying fast. Mature in April and May.

DETAILED DESCRIPTION.

Exterior characteristics. The worm varies considerably in size, but averages about three inches in length, by a width of from two to three lines, tapering considerably towards the tail. The color is pale flesh, with a bluish cast, and quite transparent, glassy, with a yellowish clitellum. Altogether, the exterior appearance of the worm is one of great delicacy, greatly heightened by its semi-transparency.

The cephalic prostomium is prominent, and divides the peristomium about $\frac{3}{4}$ of its width (fig. 3). This, the first somite, is wider than any of the following. Somites ii and iii are next in size, and about equal in width. Somites iv to xi are smaller, about equal in width, slightly decreasing backward. Somites xii and xiii are smaller than any of the other anterior somites, and of about the same respective width (fig. 2). No dorsal pores.

The clitellum (figs. 2 and 15) commences with somite xiv, though xiii is generally somewhat thickened. The clitellial somites xiv, xv and xvi are very wide, about as wide as somites ii and iii, and of the same size. Somite xvii is much smaller. This somite carries the male pores and papillæ (fig. 15). These are situated in the posterior part of the somite, almost on the edge of the intersegmental groove (fig. 15). The papillæ are slightly raised around the opening of the sac in the penial setæ. The papillæ are situate close together very near the median line of the body, a short distance only from the ventral ganglion. The papilla is oblong, sigmoid, with a pore for the setæ at inner end. Between it and the intersegmental groove is seen the slit in which open the prostate and the spermduct. It is situated slightly to the outside of the penial papilla (fig. 14).

The oviducal pores are in the anterior part of xiv, generally in a depression anterior to and more ventrally located than the inner couple of setæ. Spermathecal pores are variable, not perceptible. The nephridio-pores are in front of the third setæ.

while the three anterior pepto-nephridio-pores are in front of the fourth setæ (fig 2). Clitellum is conspicious, occupying somites xiv to xvii, encroaching slightly on xiii (fig. 2 and 15).

In viewing the caudal end of the live worm a number of irregular white spots are seen in mature specimens. These are rows of mature ova which agglomerate there sometimes in large quantities. How they finally find their way through the oviduct is not readily explained.

Setæ (figs. 2 and 4). As usual the setæ begin in somite ii. All except those in the penial sacs, are sigmoid and arranged in couples of two, eight in each somite. The ventral setæ are about $\frac{1}{3}$ closer than the lateral ones. Thus if we consider the distance between the inner and outer couples to be 50, that between the setæ of the outer couple is 30, that between the setæ of the inner couple 22, that between the inner couples 40. This being the distance in somite xxvii, where it may be said to be normal. In the region of the clitellum, and posterior to it, the inner setæ are unequally distant in the respective somites. Thus we may consider the inner setæ 1 and 2, to have the normal distance from each other in somites xii to xxvii. From these two somites the setæ in the inner couples converge toward somite xviii in which the setæ are about $\frac{1}{3}$ as far apart as in xii and xxviii. In xvii the setæ of the inner couples are wanting.

The innermost or row No. 1, forms a continuous line from one end of the body to the other, while the row No. 2, forms an angle with somites xvii and xviii at the apex. The setæ in rows 3 and 4 are parallel and normal. The seta 1 in xviii is present (pl. xii, fig. 4).

This arrangement of the setæ appears very constant, and is characteristic of the species, the details being somewhat different in the other species of the genus, while the general characteristics are the same. The normal setæ (fig. 16) of the clitellum are not smaller than those of other parts of the body. The penial setæ are, however, very much the largest.

Penial setæ (fig. 17). The two pairs of sacs containing the penial setæ are situated in front of the spermiducal pore in somite xvii. They open immediately in front of that pore, in a slit, at either end of which is situated a pore, each pore being the outlet for the respective fork of the penial sac. The two sacs are connected at the upper margin as usual by arciform muscles. Each sac contains not less than two, and sometimes three or four setæ, straight or slightly curved, but not sigmoid. The setæ vary considerably as regards shape, but resemble each other in not being sculptured, and are only marked by rings. The penial sac reaches to the upper part of the muscular part of the prostate.

INTERIOR CHARACTERS.

The *Septa* begin between somites iv and v. Those between vii and viii, and following as far back as somite xiv, are slightly thickened, all, however, being of the ame general thickness,

The *body wall* contains the usual layers. The hypodermis is slightly thinner

than the circular muscular layer, and this again is thinner than the longitudinal muscular layer. The clitellum is perfect, but somewhat thicker on the upper part. The glandular layer is very thick, being about ten times thicker than the two muscular layers combined. The longitudinal fibres are nowhere arranged in such feather-like bunches as in Lumbricus, but much more irregular, with a faint tendency to feather-like bunching. This is the rule both in the clitellum and elsewhere. This stratum of longitudinal fibres is, as usual, interrupted in four places by the setal grooves, though there are also fibres between the setæ. In the center, between these grooves, the layer is thickest, from there gradually tapering towards the setæ. The under side, or the ventral part, of the layer is somewhat thicker than the dorsal part.

The clitellar glands are less regularly paired than in Lumbricus though the general arrangement is that of two or three rows of glandular cells together. The clitellum is very thick and developed all around the body.

Alimentary canal (fig. 1). The buccal cavity is eversible to a remarkable degree, so much so that it is often projected like a large sac or bladder, covering more or less perfectly the prostomium and part of the peristomium. Its walls are very thin and transparent. The pharynx commences with the prostomium and covers somites i, ii, iii, but is only dorsally developed. It is much and irregularly folded, the sinuses being sac-like and not parallel, the largest ones being in somites ii and iii. The muscles of the pharnyx are thickly covered with salivary glands. Superiorly these glands project along the under side of the muscular bands, which extend backward, thus forming three rows of parallel projections tapering from base to apex. The anterior of these salivary glandular masses is the largest, the third, or the most posterior one, the shortest (fig 6). The posterior half of the salivary glandular mass forms one single projection equal to all the anterior ones together. This gland is connected with and partially rests on two muscular bands attached to the body-wall between somites vii and viii.

Œsophagus commences between iii and iv, extending backward to somite xvi, being slightly differentiated in xiv, xv, and part of xvi, as a tubular intestine (fig. 1). Œsophagus is much sacculated, first rising upward and forming a sigmoid plexus in somite vii, after which it lowers itself somewhat in viii and then extends gradually backward to the sacculated intestine, at the same time gradually diminishing in size. The tubular part in xv or between xv and xvi is the narrowest part of the œsophagus. The glandular epithelium of the œsophagus is very narrow in the anterior somites, or those in front of the clitellum, and the blood sinuses in them are narrow. In the anterior part of the clitellum the epithelial villi become greatly elongated with increased blood supply, while in the central part of the clitellum these blood sinuses become very large, occupying the largest part of the epithelial lobes. The nuclei in those epethelial cells are everywhere round.

The *sacculated intestine*, fig. 1, *s. i.*, commences in xvi, is generally about four or five times wider than the tubular intestine. It does not increase gradually, but at

once, in which it differs from the corresponding organ of the two other species described here.

Septal glands (fig. 1). The septal glands of the œsophagus are found paired in somites vi, vii, viii and ix. They are all comparatively small and very thin and flat. The posterior ones are smaller, but the difference between the glands is not so great as for instance in some species of Ocnerodrilus, or as in *Deltania Troyeri*. They are more nearly of the same size, and they extend all around the œsophagus and are more or less divided in several separate lobes. We can, however, always distinguish one pair in each somite connected with the septum below the alimentary canal, extending upward with its free upper lobes, which do not connect.

Nephridia (figs. 19 and 20). The nephridia commence in somite ii, and are found in all posterior somites. The three anterior nephridia—in ii, iii and iv—are slightly different as to size and outward form, and may be considered as a kind of pepto-nephridia. They open, also, differently from other nephridia, their pores being in front of and a little interior (nearer the ventral ganglion) to seta 4, while all other nephridia open in front of and interior to the third seta. The nephridiopores of the clitellum are considerably larger than the pores in the other somites, and appear like large, transparent discs when viewed from the outside. All nephridia possess a vesicle or bladder next to the body-wall. A small collar of tubular cells surround the nephridio-pore. The vesicle is smaller in the anterior pepto-nephridia, gradually increasing in size backward, being largest in the post-clitellar nephridia, where it is several times larger than in the pepto-nephridia. In the three pairs of pepto-nephridia, the vesicles are almost circular, and of the same size in the three nephridia. That of the first common nephridium in somite v is of about the same size as the pepto-nephridial vesicles, but from this on the bladders increase gradually, but slowly, in size to the end of the clitellum. But in somite xviii and following to the end of the body, the vesicles are much larger, about twice as large as those in the clitellum. Thus the nephridio-vesicles in the clitellum are about three to four times shorter than the tubular part, while the post-clitellar vesicles are half, or more than half, as long as the tubular part or duct, when ordinarily folded. In the pepto-nephridia, the vesicle is about five times shorter than the folded tube, and the tubular duct extends more backward than in the other nephridia—especially so in the first nephridium encroaching on the next posterior somite, reaching diagonally across the somite, while all the other nephridia run parallel with the intersegmental grooves. This diagonal position of the nephridia is, however, not always constant, except in the most anterior nephridium. The vesicle in the posterior nephridia consists of two more or less distinct lobes, the posterior one (to the duct), which is more rounded and bladder-like, forming a cœcum, and the anterior, which is elongated or deltoid. This difference is more pronounced in the posterior than in the anterior nephridia, most so in the nephridium in somite xviii, which nephridium is generally the largest of all. From this somite the nephridia diminish somewhat in size, both anteriorly and posteriorly. The posterior margin of the vesicle is considerably lobed, and in

general outline convex. The anterior margin is convex-deltoid, with the apex at the exterior pore.

The single duct from the vesicle leaves the vesicle in a different manner in the respective nephridia. In the pepto-nephridia it ascends from the center of the vesicle; in the anteclitellar vesicles it leaves from the apex of the deltoid longer part of the vesicle, while in the postclitellar nephridia it leaves from the side of the vesicle below the apex. The inner structure of the nephridia corresponds almost exactly with that of the nephridium of Argilophilus, which genus, however, does not possess a vesicle. With this exception, the nephridia of the two genera might be considered as almost identical. The most characteristic feature is that the short single duct from the nephridio-stome after joining the nephridial body, does not enter it as a single tube, but as a spongy duct full of irregular and connecting ductules, which later on join into one larger branching canal, the ductules, or arms of which enclose the two regular underneath-lying ducts. At the inner bend of the duct the ductules disappear and the returning lobe contains three main canals, one of which is ciliated. This arrangement reminds us greatly of the one observed in certain leeches and described by Bourne. The vesicles consist of an outer muscular layer, which extends all around the bladder, and from it, along the duct through the clitellum or body-wall, to the exterior pore. Between it and the cœcal epithelium there is a continuous row of connecting chambers probably analogous with the ductules of the ducts. This epithelium is furnished with some few blood-vessels. The duct from the bladder to the nephridio-pore is not otherwise differentiated, the glandular cells of the clitellum joining directly on the muscular duct. Before reaching the pore but while in the body-wall, the duct is enlarged, forming a small pear-shaped urinary bladder, which again opens into a narrow duct surrounded by a row of long tubular cells, which open directly into the duct. These cells form a veritable collar, the upper cells lining the inner surface of the nephridio-pore (fig. 49). This in the clitellar nephridia. In the nephridia posterior to the clittellum, the long tube between the vesicle and the pore is entirely wanting, the bladder connecting directly with the collar of tubular cells (fig. 50). The tubules, or vacuols, in the vesicle collect into at least two tubes, which run downward between the muscular and glandular layers of the vesicle and apparently open on either side at the beginning of the collar at the nephridio-pore (figs. 49 and 50). The secretion from this glandular layer of the bladder may be of such nature as to facilitate the ejection of coarse matter such as calculi which are found often in enormous quantities in the vesicle or seen as just ejected through the pores. The single duct which leads from the bladder to the nephridial body proper or the folded canals, apparently does not connect directly with the ductules or vacuols of the bladder, but opens directly into the large central chamber of the bladder, which again connects directly with the collar of the nephridio-pore. For a more detailed account of the canals of the nephridia in these two genera see the description of next genus, Argilophilus. Below the nephridial collar in *Deltania elegans* is found a large branching body, probably a ganglion. It sends out branches to the nephridial collar, though in my sections I have not seen their actual connection with the collar. In

fig. 50*b*., the section is made through the junction of the nephridio-vesicle and the collar, and the ganglion (*n. gl.*) below is small, not yet branched. In fig. 50*c*, the section is made close to the pore where the ganglion (*n. gl.*) is branched. These branches always extend towards the collar, never the other way. Both these sections from which the drawings were made are not quite in right angle to the longitudinal muscular layer, but slightly slanting.

The nephridio-stome is rather large, but very transparent and quite difficult to detect. It is flat, rosette-like and placed half-way between setæ 1 and 2. The duct descending from it is remarkably thin, straight and never winding. The nephridio-stome is normally situated, piercing the anterior septum as usual. There is no central cell and nucleus larger than the other, but several smaller cell nuclei are visible in the center below the large marginal cells, which are about 16 to 18 in number and as usual placed in a crescent. Between these cells and the real margin of the lip there is a row of smaller cells and nuclei, the latter being slightly lower than the inner large nuclei, but sufficiently situated in the same plane to be seen at the same time.

Testes consist of two pairs of small bodies, as usually situated in somites x and xi, attached to the septum close to the body-wall in the anterior part of the somite. They are deeply lobed and the lobes are very narrow, parallel and generally three or four in number. The testes are free, not enclosed in the sperm-sacs.

Sperm-sacs (figs. 5 and 6). There are two pair of sperm-sacs, one pair in somite xi and one pair in xii, attached to the anterior septum in the somite, rather high up, but below the œsophagus. The four sperm-sacs are of about the same size, comparatively small, and deeply lobed very much like the posterior sperm-sac in *Ocnerodrilus Beddardi*, etc., none of the lobes being very much larger than the other. It must be remarked that the sperm-sacs are not situated in the same somites as the testes, somite x possessing testes, but no sperm-sacs, and somite xii possessing sperm-sacs, but no testes. The respective sperm-sacs are not connected with each other and there is no median sperm pouch. The trabecula or muscular divisions of the sperm-sacs are numerous and the chambers enclosed by them are comparatively small.

Spermducts and rosettes (figs. 7, 8, 11). There are two pair of ciliated rosettes, one in xi and one in xii, as usual. They are very large and folded, deeply crumpled and very prominent, occupying about $\frac{1}{4}$ of the somite. The funnels are wide, with a slight posterior swelling. The spermducts run backward and sideways, connect in xii, and continue to somite xvii, where they leave the body-wall, ascend slightly and connect into one single duct, which opens out jointly with the prostate, in the posterior part of the somite. The duct does not enter the prostate, but both open jointly in one slit, running parallel to the intersegmental furrow. The spermduct is throughout of the same size, only widening out just previous to entering the rosette. The lower descending part of the duct, between the spermiducal pore and the bend where it starts forward, is slightly narrower than the anterior part.

Prostate (fig. 8). There is one pair of prostates of rather prominent size extending parallel with the intersegmental groove reaching almost across the somite. The shape of the prostate resembles at the top somewhat a curved feather, the inner apex being helix-like, curving backwards. This form appears quite constant and while I found the length and the width of the prostate to vary, I never found one, which did not show the helix-like, convolution. The thickness of the prostate varies considerably. In some specimens it was almost twice as thick as in others, the increased thickness being caused by a gradual widening toward the inner apex. In some specimens the prostate was longer, more slender and its longitudinal sides almost parallel, but the convolution was generally always thickened. In most instances the convolution could be considerably straightened out by a pushing with a needle, but it would when released assume its natural helix-like form. The spermduct connects with the muscular part of the prostate in the muscular layer of the body-wall. The sac containing the penial setæ is situated immediately anterior to the prostate and somewhat closer to the ventral ganglion in line with the regular setæ, but opens in the same pore with the prostate and spermduct. (Figs. 8, 51, 52, 53.)

A cross section of the glandular part of the prostate shows that it is composed of two layers of cells, the outside one containing large cells of flask-like shape, the inner are narrower rectangular cells. The contents of both layers resemble each other greatly and are difficult to discern. Both layers of the prostate contain numerous blood vessels arranged like radii in a circle, penetrating both of the cellular layers. But the inner layer is seen to also possess a vascular system of its own with many smaller vessels similarly arranged. These vessels are generally wider at the periphery of the prostate and narrow toward the center, many if not all collecting in a network of capillaries spreading on the inner surface of the prostate (figs. 55 and 56). Otherwise these vessels do not anastomose. All these vessels are fed by a branch from the ventral vessel of the body, which divides on the prostate into two or three large branches which again fork toward the apex of the prostate in many smaller ones, as in *Deltania Troyeri* (fig. 45).

This junction of the various male organs is affected in this manner. The two spermducts run jointly on the top of the inner longitudinal muscular layer of the body-wall. When reaching the lower or muscular part of the prostate they turn and run parallel to it. Immediately before reaching the place where the prostate enters the wall, the two spermducts fuse into one duct, the lumen of which then is wider than the adjoining part of the prostate. This duct joins the prostate in the longitudinal muscular layer of the body-wall. After reaching the transverse muscular layer this duct joins the pore of the penial setæ (figs. 51, 52, 53).

Spermatheca (fig. 13). The spermathecæ consist of very minute bodies, pear-shaped in outline, and of extremely delicate structure, without any differentiation of the wall in a muscular and glandular layer. In size, the spermatheca is not much, if any, larger than one-half the width of the somite, when contracted in alcohol. But the most peculiar feature of this organ is that it is variable in number and position.

In one specimen I found only one spermatheca, situated in the center of the ventral line, between somites ix and x, but in x. Another specimen had two spermathecæ, one in ix/x, another on the left side, between x and xi. Another had two spermathecæ betweeen x and xi, one on each side. Another had two spermathecæ between ix and x, one in center of median line, and one on the right side, always attached to the intersegmental wall. This arrangement and variability of the spermathecæ reminds us of the spermathecæ in Microchæta, where the number varies on either side; but in other respects there is no similarity between the two. The exterior spermathecal pores are not conspicuous, and not perceptible when viewing the outside of the body, mounted, for instance, in glycerine. As will be seen, the spermatheca in this species differs very much from those in *Deltania Troyeri* and *Benhami*, in which two species this organ is constant, and furnished with two diverticula each. The spermatheca in *Deltania elegans* resembles greatly in structure a sperm-sac, from which it only differs in size and in position. It reminds me greatly of the peculiar organ described by me in *Ocnerodrilus occidentalis*, where, apparently, the posterior testes have become modified, and assumed the function of spermathecæ, with a distinct and ciliated duct perforating the body-wall.

The *spermatozoa* are always found agglomerated in sphærical masses in the spermatheca, hardly regular enough to be designated as spermatophores. The tails are long, either extending straight out, or arranged screw-like in the same direction around the sperm-ball. These balls vary greatly in size, some being twice as large as others, but they are always round and apparently globular (fig. 13).

Ovary and Oviduct (fig. 9). As usual the ovary is found in xiii. It offers no great peculiarities. It is rather deeply lobed and very large. The oviduct opens in xiv, with its funnel in xiii. The oviducal funnel is very thick, substantial and round, with a circular and very regular outline. The figures (5 and 9) give correctly its outline, but the depressed folds have been too distinctly marked. There is no ovisac, and the ovary and oviducts are entirely free.

Blood vessels. The dorsal vessel emits three pair of hearts in x, xi, xii, and the ventral vessel is forked between somites ix and x. The blood is yellowish-red, more decidedly yellow than red. There are but few blood vessels on the nephridio-tubes and none on the nephridio-vesicle.

The *ventral* nerve-cord is considerably wider in the posterior part of the somites where it emits the customary pair of nerve fibers. In the anterior part where the single septal nerve pair is emitted, the nerve-cord is quite narrow. In *Deltania Troyeri* the nerve-cord is quite uniform without any nodular enlargements, as wide at the anterior as at the posterior end of the somite. The brain is narrow, slightly curved and the posterior sinus shallow. It is situated in somite ii (fig. 6).

Deltania Troyeri.

Figs. 21 to 39.

Deltania Troyeri Eisen, Zoe, iv, 251, October, 1893.

Size about 1¼ inch by ½ line. Septal glands comparatively large, the one in vi the largest. One pair of large, opaque spermatheca, furnished with one pair of diverticula, which are about ½ or more longer than the spermatheca proper. Spermsacs in x and xi, not lobed. One developed seta in each sac of penial setæ. Prostate is tubular, not helix-like, with the top either straight or bent at right angle, projecting backward. The exterior penial papillæ not as prominent as in the preceding species. The inner couples of setæ are further apart than in the following species.

Habitat. This species was first brought to my attention by Professor Carlos Troyer, of San Francisco, who found it, together with the preceding species, in the Golden Gate Park, in San Francisco, immediately north of Strawberry Hill. It occurred there in sandy depressions, where the rain and drainage water had moistened the soil in March and April. As the soil dried up the worms disappeared. The worm is very scarce at any time, and not one specimen is found to every hundred of *Deltania elegans*.

Exterior characteristics. Exteriorly this species is characterized at once from *Deltania elegans* by being very much smaller, as much so as an Enchytræus is smaller than an average medium-sized Lumbricus. The length in the largest specimens is about two inches, when stretched to its full capacity, though the average ones hardly reach one inch. The width is less than one line at the clitellum and less than ½ line at the tail end. The first somite is much longer than any of the following. The second somite is next in size, while all the others are smaller and of very much the same proportions as in *Deltania elegans*. Thus iii, iv and v, are larger than the following, and those between v and xiii are smaller and of about the same size.

The clitellum occupies the same somites as in *Deltania elegans*, or from xiv to xvii, with the two outside somites smaller than the central ones. The body tapers towards the tail end, the last somites being somewhat larger than the others and rather obtuse.

The color is pale flesh, with a darker, yellowish clitellum. The whole body is very transparent, just as the former species, but much less so than in the following. It is a very tender worm indeed, and can only be brought home alive with great care, as the least increase of temperature is apt to kill it. In no instance did I succeed in keeping it alive more than a couple of days. In this respect, however, all the species of the genus are very much alike, and if there is any difference the larger species is the most tender.

Setæ (figs. 21, 24 and 39). The general arrangement of the setæ is similar to that of *Deltania elegans*, but the two inner setæ are much less close together, in comparison with the two outer ones, than in the latter species, but not as close by one-half as in

Deltania Benhami. In the genital region, the distance between the two inner setæ diminishes toward the male pore, almost in the same way as in *Deltania elegans*, with, however, a slight but characteristic difference. The inner or first seta in xviii is often, but not always, wanting, probably falling out when young, before its full development, as more frequently a rudimentary seta is seen in place of a fully developed one.

The first and second setæ in xix and xx are closer together than normally, but already in xxi the setæ have regained their proper distance. Again, anterior to the male pore, the setæ 1 and 2 in xi to xvi are closer than normally, those in xiv to xvi are equidistant, while those in x to xiv rapidly approach. If we thus compare with *Deltania elegans*, we find that the arrangement relatively in front and behind the male pore is reversed. While in *Deltania elegans*, the anterior setæ quickly converge, the posterior ones approach slowly. In *Deltania Troyeri*, the opposite is the case.

The shape of the setæ in the two species is very similar. Compared again with the arrangement of the setæ in *Deltania Benhami*, we find that in the present species the setæ in the ventral couples, as well as those couples themselves, are much further apart than in *Deltania Benhami*. The deltoid arrangement, also, is different in the two species, of which the figures give a better idea than any lengthy description (figs. 24, 39, 40).

The *sacs of penial setæ* (fig. 33) are found as usual in the vicinity of the male pore in xvii. There are seldom more than one seta in each sac. This seta is long, slender, almost straight, occupying the whole length of the sac. Now and then there is a rudimentary seta in the same sac, but never more than one developed seta. In *Deltania elegans* there are three or four setæ in each sac.

Alimentary canal (figs. 26 and 27). The buccal cavity extends superiorly to ii, inferiorly to v. The pharynx ends in v, and is much less developed than in *Deltania elegans*. The upper fold is, however, very large. There are one pair of long and narrow salivary glands in each of iii and iv, and one pair very large compact ones in iv. The œsophagus commences in v, and rises to a sigmoid plexus in viii. It is greatly contracted at the septa. In xv and xvi it narrows down to a tubular intestine.

The sacculated intestine commences in xvii, but attains its full width first in xix or xx. There is no gizzard, no calciferous glands nor pouches of any kind attached to the alimentary canal.

Nervous System (fig. 28). The characteristic feature of the nervous system is the even width of the ventral ganglion, the two sides being nearly parallel throughout, with almost imperceptible contractions at the septa. In *Deltania elegans* this contraction is very prominent, and the ganglion is almost twice as wide in the posterior part of the segment as in the anterior one. This characteristic appears constant. In *Deltania Benhami* the ganglion is narrowed somewhat at the septa, but the posterior part in each segment is not any wider than the anterior part.

Septal Glands (figs. 26, 27, 29). When the worm is laid open and the cavity viewed from above, it is seen that there are 4 pair of septal glands surrounding the œsophagus in somites v, vi, vii and viii. In this view the anterior gland appears the largest, and the posterior one in viii the smallest. This is, however, only an illusionary appearance, caused by the position of the glands. There is in reality not any very considerable difference in their size, as may be seen when separated and spread out. Seen in a slightly eccentric longitudinal section, the gland in vi appears the largest both above and below the œsophagus, though in some sections the lower part is not as large as the lower part of the gland in vii. The anterior gland in v is short but broad. The one in vii is larger than those in v and viii, but smaller than the one in vi. The upper part of the gland in viii is larger than the corresponding part of v, the lower part of the latter being the smallest. As will be seen, all the glands are developed, both superiorly and inferiorly, as regards the œsophagus, but the glands on either side in the somite do not connect, but only touch. There is a slight, but irregular lobing of the glands, frequently unequal on either side, as one gland may be almost entire, while the other again is furnished with three indentations. On the under side of each main gland there is a smaller lobe, almost entirely separated from the rest (fig. 29). The glands are furnished with blood from the subœsophageal longitudinal blood-vessel which projects a branch to each gland, on which it again divides in two or three parts (fig. 29). I may add that the septal glands are very large, almost filling the respective somites, and as compared with those of *Deltania elegans*, about three times as large, considering however the relative size of the two species. The glands are nearly similar to those of *Deltania Benhami*, but with more unequality as to size.

Salivary or Pharyngeal Glands (fig. 26). These glands resemble those of the preceding species, *Deltania elegans*, in general appearance. There are two very long glands behind the brain, attached on the underside of the two long muscular bands which stretch upward. The anterior one of these is the smallest and rather short. the second in order from the brain is the longest. The posterior gland, which forms the posterior projection of the pharynx, is much shorter, more compact and rounded than the corresponding gland in *Deltania elegans*. The whole mass of glands projects much less posteriorly than the glandular mass of the pharynx in that species.

Spermatheca (figs. 30, 31, 32 and 39). These organs are prominent and characteristic of the species. There is one pair in somite ix opening in the intersegmental groove between that somite and viii. The external pore is in front of the inner couple of setæ, but not interior to the setæ. The organs are thick, opaque and of the form of pointed sacs, each one with two diverticula, one on each side, which connect with the main sac close to the external pore. The outline of the sac is irregular in some places, toward the inner apex assuming the appearance of one or more warty diverticula, which, however, never assume the size of the diverticula. Of these latter there are one pair which are slender, cylindrical, of more or less irregular outline with the apex sometimes slightly wider, sometimes helix-like, turned on itself. The lower part of the spermatheca is muscular, but this muscular part is quite small,

not extending above the junction with the diverticula. In general form the spermatheca resembles that of the following species, *D. Benhami*, but the outline of the main sac is less regular and the diverticula are larger, being about one-half as long as the main sac (figs. 30 to 32).

Testes. As usual there are two pair of small testes occupying somites x and xi. They differ in nothing particular from those of the other two species of the genus.

Sperm-sacs. There are two pair of sperm-sacs, one each in somites x and xi. They are long, not very opaque bodies, occupying a large part of the somite, though not filling it closely. The spermatophoric spherules are comparatively large, globular. The sperm-sacs are not greatly lobed, extend considerably in length from the dorsal to the ventral side, and are of more undecided shape than the sperm-sacs of *Deltania elegans* and *Benhami*. They are also, comparatively, much larger (principally higher) than in that species. It will be noticed that the sperm-sacs occupy somites x and xi, while in *Detania elegans*, *Benhami* and *dubia* they occupy somites xi and xii.

Ovary and Oviduct (figs. 35, 36, 37, 38). As might be expected the ovary is situated in xiii. It offers no characteristics of interest. There is no ovisac. The oviduct is as usual funnel-shaped, either deeply cut or folded on one side, the inner funnel in xiii, the ovipore in xiv. Close to the oviduct in xiv there is a very peculiar sac (figs. 35 *et seq.*), of the size of the oviduct or smaller. It does not open directly in the oviduct, and it has the general shape of a septal gland with many rounded lobes arranged as the petals in a rose. The epidermal covering does not closely cover the inner cells which are irregular, apparently not closely packed, of uneven size and shape, round or conical, each with a round nucleus, and grainy cell contents. This gland does not connect with the opening of the oviduct funnel, from which it is separated by the septum between xiii and xiv. There is one pair of those glands, one behind each oviduct. The gland is affixed to the posterior part of the anterior septum in xiv. A similar gland does not exist in *Deltania elegans*. As to the nature of this organ I can say nothing definite, and I hesitate to consider it as an ovisac, until a more extensive material will allow other investigations.

Spermduct and Prostate (fig. 33). As in the preceding and following species, the spermduct and prostate open in the same pore in somite xvii. The spermduct opens slightly posterior to the prostate and also more outwardly, though both organs closely join at the pore. The spermduct is quite wavy throughout its length to the ciliated rosettes, which as usual are found in x and xi, The rosettes are less folded and crenate than those in *Deltania elegans*. The prostate differs somewhat from the one in the latter species. The muscular duct is not helix-like at its upper end, either straight or bent at right angle to itself, with the distal end pointing backward, being parallel to the longitudinal axis of the body. The relative size of the prostate is in

this species much larger than in *Deltania elegans*, which appears to be characteristic also with nearly all the other organs. The upper glandular part of the prostate is about three times wider than the lower muscular part. The latter is about equal in length to the penial setæ and their sacs.

Genital or exterior *male zone* (fig. 25). In somite xvii there is a pair of ventral papillæ close to the ventral ganglion, and situated in the transverse median line of the somite. In these papillæ open the penial setæ, in the place which otherwise would be occupied by the regular setæ. Between these papillæ and the ventral median line of the body, somewhat nearer to the posterior margin of the somite, are seen on either side a circular cup-shaped depression, from the center of which is spread backward a large fan-shaped branch of muscles connecting with the posterior intersegmental groove. In the center of this suctorial organ, and at the very point from which the fan-shaped muscular fascicle starts, is situated the exterior opening of the spermduct and the prostate. In the median line between the suctorial cups is a smaller triangular depression. The anterior part of the somite is raised and thicker than the posterior part, or rather there are two large anterior folds, and several smaller posterior ones in the vicinity of the male pores (fig. 25).

Deltania Benhami.

Plates xv and xvi, figs. 40–48.

Deltania Benhami Eisen, Zoe, iv, 212, October, 1893.

Size about 1 inch by $\frac{1}{16}$. The inner couples of setæ as well as the setæ in the inner couples are much closer together than in any other species. The spermatheca are large, opaque, situated in ix, and opening between ix and viii, with two diverticula, which are less than $\frac{1}{2}$ as large as the main spermathecal sac. A small species, in many respects resembling *Deltania Troyeri*, but very distinct by the above characteristics.

Habitat. I have found this worm only in a gulch or cañon at the outlet of the waterworks and dam, known as Lake Chabot, east of Alameda and San Leandro, in Alameda Co., California. The worm is very scarce and lives under damp leaves in the very top layer of the soil around the roots of trees. The exact locality is to the right of the gate which closes the reservation, down by the creek, not far from the wire fence. It occurs here alone, not mixed up with any other species, and to all appearances this species is a true native and not introduced. It is an exceedingly delicate worm, almost transparent, white, with yellowish clitellum, very impatient of being handled and can only be kept alive with great care. It is much more transparent than any of the other species.

Exterior characters. In general appearance, the worm resembles *Deltania Troyeri*, but is slightly larger in size. The second somite is much narrower than in that species, being larger than the third somite. But it is especially as regards position of the setæ that the greatest external difference exists (fig. 40). The ventral setæ in one species are much closer together than in the other species of the

genus, and average about twice or three times as close as in *Deltania Troyeri*. This is a prominent and constant characteristic. The characteristic feature of the genus, which consists in the narrowing together of the ventral setæ on both sides and towards the male pore in xvii, is readily seen in this species. On account of the already very close approach of the ventral setæ of each couple, this narrowing together is, however, less perceptible in our present species, but it is still considerable and readily seen. The figure (fig. 40) will illustrate this better than any lengthy description. Not only does this approach of the setæ exist on both sides of the male pore, but it is also seen towards the spermathecal pore, though here in a smaller degree. In *Deltania Troyeri*, there is not a trace of such an increased approach of the ventral setæ towards the spermathecal pore. Another characteristic as regards the setæ is that the ventral or inner couples are much closer together than in the other two species described here, so close that the main bodies of the spermathecæ almost touch.

The spermathecal pore is situated in the intersegmental groove between viii and ix, in front of seta 1. In *Deltania Troyeri*, the spermathecal pore is in front of the corresponding seta 1, but considerably more lateral, and on account of the greater distance of the ventral couples of setæ, the spermathecæ in that species are much further apart, and do not crowd the ventral ganglion. Oviducal pore as usual in xiv. Penial setæ on papillæ in xvii, opening in the male pore. The clitellum comprises three full and wide somites, xiv, xv, xvi, and two smaller ones, xiii and xvii, as in other species.

The genital region (fig. 48) around the male papillæ is much simpler than in *Deltania Troyeri*. The two papillæ are situated much closer together, and there are no suctorial depressions with their fan-shaped arrangement of muscles. The penial setæ are very slender, sickle-like, bent at the free apex, with a narrowed and sharp point. There are a dozen or more external fibres of exceeding thinness stretching from the anterior part of somite xvii to the posterior part of xviii. These threads, however, exist only in the longitudinal groove between the papillæ, all run parallel with each other and with the long axis of the body (fig. 48). As to their nature I am not at all certain. They are apparently too thin to be muscles. The clitellum proper in this as in the preceding species ends at the papillæ or male pore. Anterior to it the clitellum consists of regular flask-like cells; posterior to it again the body-wall has assumed its regular appearance. In *Deltania Troyeri* the clitellar thickening stops just before it reaches the papillæ, but in *Deltania Benhami* it stops just as it reaches the male pore. The papillæ, however, continue to the posterior end of the somite.

The length of the species is about 1 and $1\frac{1}{4}$ inch, by $\frac{1}{16}$ to $\frac{1}{8}$ inch wide, tapering towards the caudal end. In fact the general form and size does not differ from the preceding species. In all I found some fifteen specimens, but they were, unfortunately, in poor condition when I arrived home, and the part posterior to the clitellum had already begun to decompose. The following account of the anatomy is, therefore, not as full as desirable, but enough is known to perfectly characterize

the species. There are four pair of septal glands in v, vi, vii and viii. The glands, as far as I can judge from dissections only, are of almost equal size, somewhat longer there than in *Deltania Troyeri*. They are equally developed on the lower and upper side of the œsophagus. The alimentary canal offers no great peculiarities. The specimens were all very much stretched, and I am not certain if the form of the œsophagus will prove constant. However, the contractions at the septa were much smaller than in any other species. The œsophagus from somite ix narrowed down toward somite xii, here it began to gradually increase in width, but the sacculated intestine begins evidently first in xvii, increasing in width gradually backwards until it reaches the region between xxvii and xxxv, where it suddenly narrows and continues as narrow to the end of the body.

Spermatheca (figs. 42 and 43). There is one pair in ix, opening between viii and ix, of the same general appearance as in *Deltania Troyeri* with minor characteristic details. The main sac is ovoid and somewhat lunate, pointed, with very smooth outline and with no trace of warty excrescences. There are two diverticula affixed halfway between the base and the glandular part. They are much smaller than those of *Deltania Troyeri*, being less than one-third as long as the main spermatheca, while in *Deltania Troyeri* the diverticula are one-half or more as long as the main spermatheca, and affixed to the muscular part close to the base. The spermathecæ open in front of the 1st setæ and are situated much closer together than those in *D. Troyeri*. The opaqueness of the spermatheca is the same as in the latter species. There is, however, a decided difference in the location of the spermatheca. In *D. Troyeri* they are situated so far apart that they do not touch the ventral ganglion. In *D. Benhami*, however, they crowd it, this approach being caused partly by the closer proximity of the ventral or inner couple of setæ, partly by the situation of the spermathecal pores which in our present form are more ventral to the setæ.

The sperm-sacs (fig. 41) are of a very characteristic form. They are larger in proportion than those of *D. elegans*, but not quite as large as in *D. Troyeri*. There are two pair, one each in ix and xii, and they do not connect with each other. Each one consists of a very large flesh-like lobe, at the base of which are seen half a dozen smaller and globular sacs, all connected at the place of adherence to the anterior septum. These different lobes, the large one as well as the small ones, are full of rounded, oblong or irregular spermatophoric sphærules. The sperm-sacs do not by far fill the somites. The form of the sperm-sacs varies to some extent, but the main character is the same in all, a large, rounded or flask-like lobe, at the base of which are several smaller ones.

Spermduct and *ciliated rosettes* as in *D. Troyeri*. The *prostate* offers the characteristic of having the lower part of the glandular sac considerably swollen, conical and gradually diminishing in size towards the apex, which again is slightly enlarged like a knob. There is only one long slightly bent or almost straight seta in each of the penial seta-sacs, both setæ opening on a small papilla, and which as far as I can see more resembles that of *D. Troyeri* than *D. elegans*. The blood is very pale yellow, paler even than in the other species. There are three strongly pulsating hearts in

somites x, xi and xii, connecting the dorsal and ventral vessels. There are also connections between those two vessels in ix, x and xiii as in the other species, but those connections consist of regular secondary vessels narrow and tubular, and in no way resembling hearts. There is no subneural vessel. The ventral vessel is divided in somite vi, and in the anterior six somites there is a heavy capillary system connecting the ventral and dorsal vessels.

In the following I have endeavored to give a comparative table of the species which I refer to *Deltania*. As far as concerns those species which I have not myself investigated the table must be considered tentative, especially so in regard to the character of *D. dubia*, the description of which by Fletcher is somewhat insufficient. I need here hardly add that *Deltania Poultoni* is the species described from Maderia by Beddard as *Microscolex poultoni*. The description given for D. *dubia* is taken from Rosa's description of *Microscolex dubius* Fletcher, and not from Fletcher's own.

DELTANIA.

	D. elegans n. sp.	*D. Troyeri* n. sp.	*D. Benhami* n. sp.	*D. Poultoni* Bedd.	*D. dubia* Rosa.
Septal glands in	vi, vii, viii, ix.	v, vi, vii, viii.	v, vi, vii, viii.	Not present.	
Sperm-sacs in	xi, xii.	x, xi.	xi, xii.	xi, xii.	xi, xii.
Spermatheca	Very small and pellucid. No diverticula.	Large, apart, with 2 diverticula each. Opaque.	Large, close together, with 2 diverticula each. Opaque	Not present.	Not present.
The *ventral* or *inner setæ* in each couple exclusive of those in the genital region, are:	Only a little closer together than the setæ of the outer couple.	Only a little closer together than those of the outer couple.	Several times closer together than those of the outer couple.	Several times closer together than the outer couple.	Several times closer than the outer couple.
Prostate, the glandular part	Helix-like at the top. Muscular part not very short.	Not helix-like; tubular, straight or bent.	Not helix-like; tubular and broad at the base. Top enlarged knob-like.		Helix-like at the top. Muscular part very short.
Gizzard	None.	None.	None.	None.	Rudimentary.
Diverticula of the spermatheca	Absent.	More than ½ as large as the spermathecal pouch.	About ½ as large as the spermathecal pouch.		
Penial setæ	Two on each side.	Two on each side.	Two on each side.	One on each side.	Two on each side.
Nephridia commence in	ii.	ii.	ii.	ii.	v.
Nephridio-pores in front of and little interior to	4th and 3d setæ. Prominent in the clitellum.	4th and 3d setæ.	4th and 3d setæ.	3d setæ.	3d setæ. Not prominent in the clitellum.
Spermducts	Remain separate up to the atria.	Remain separate up to the atria.	Remain separate up to the atria.	Remain separate up to the atria.	Unite to form one tube on each side which opens in the muscular part of the atrium.
Posteriorly to the clitellum the setæ have regained their normal distance in somite	xxvi and xxvii.	xxi.	xxi.	. .	xxiii and xxiv.

ARGILOPHILUS.

Argilophilus Eisen, Zoe iv, 252, October, 1893.

Prostomium encroaches on somite i. Eight setæ in four couples, ventral, lateral and dorsal, commencing in somite ii. The setæ of the inner couple not converging towards the male pore, but closer set than the setæ of the outer couple. The alimentary canal consists of an eversible buccal cavity, a pharynx, œsophagus, gizzard, tubular intestine, sacculated intestine, typhlosole, but no œsophageal glands or pouches. Clitellum not developed ventrally, occupies somites xiii to xviii.

Spermathecal pores, one pair vii/viii and one pair viii/ix. Ovipores in xiv. Male pore in xviii. One or two rows of ventral intersegmental papillæ. Two pair of spermathecæ. Testes in x, xi. Sperm-sacs paired in x, xi, xii, generally enclosing the ciliated funnels and testes. Two pair of ciliated funnels. Two pair of sperm-ducts, which join a pair of very large, tubular-coiled prostates in xviii, at the upper end of the muscular duct. Two penial setæ open in the same pore, but not in the same duct as the prostate.

Dorsal vessel and ventral vessels connected by 5 pair of hearts in xiv to x. No. subneural vessel. Blood red. Many blood vessels on the nephridia. No pepto-nephridia. The nephridio-pores variable as to location, the majority open in front of or lateral to the 4th setæ, though many open interior to the 4th setæ. No cœcal bladder at the exterior pore. Large earthworms with thick round bodies, of pale flesh color, marbled bluish.

Distribution and habitat. The genus Argilophilus appears to be an undoubted native of the Pacific Coast. Specimens have been found in the San Joaquin Valley in California, and as far north as British Columbia (Vancouver Island). In California these worms are our most common earth worms, appearing close to the surface with the advent of the rains in the autumn and disappearing deep in the soil with the dry weather in May, after which time they are not any more found in even locally moist places. During the summer months I have sometimes dug up these worms from a depth of 5 to 6 feet or more, each worm tightly rolled up as a little ball and apparently encysted in a chamber of clay, the inner surface of which is smooth and hard. In these cysts the worms pass the dry season. These worms are hardly ever found outside of heavy adobe or clayey soil; the more clayey the soil, the better the worms appear to thrive, provided also the soil is rich and fertile. In poor soil the worms are seldom seen, and the best indorsement for a soil is that it contains worms of this genus.

The color of the worms of this genus is fleshy pink, thickly marbled, with steel or slate gray, (fig. 132). The clitellum is yellowish red, and the whole anterior part is pinkish. The color of these worms is very handsome and distinguishes them from the deep brown Allolobophora so common in moist or swampy places in this State.

Exterior characteristics (figs. 125–131). The most prominent exterior feature of this genus is the color which has just been described. Another is the frequent eversion of the lining of the buccal sac (fig. 130). As to size the worm must be

considered as our largest earthworm, though very variable, as might be expected. The smallest adult worms measure about $1\frac{1}{2}$ inches by 3 lines, the largest again 6 inches by 4 to $4\frac{1}{2}$ lines, the size appears to depend greatly on the locality and richness of the soil. The prostomium divides somite i to about $\frac{1}{2}$ or $\frac{2}{3}$ (fig. 130). Somites vii, viii, ix, are larger than the other anterior somites. The clitellar somites (figs. 125 to 131) are large, the post-clitellar ones are very much smaller. The spermathecal pores are more or less conspicuous (fig. 129 *spth.*), sometimes hardly visible, at times again elevated and appearing as small round rings. They are situated just lateral to setæ 2, but of course in the intersegmental grooves between vii/viii and viii/ix. The ovipores are closer together, situated a little more ventrally than setæ 1, sometimes, if not generally, connected by a depression. The clitellum is only developed dorsally and laterally, the ventral part between the male pores being normal and appearing as considerably depressed, in hardened specimens the depression reaching as far forward as to the center of somite xiv or the ovipores.

The male pores which open in line with setæ 2, are situated on either side on an elongated papilla, which again is more or less surrounded by a circular depression, outside of which is seen a high semi-circular ridge, which is thicker anteriorly and posteriorly than laterally (fig. 25, 129). The penial setæ are one pair in each pore, and are seen protruding through the male-pore.

The regular setæ are sigmoid, not greatly bent. The setæ of the inner couples are closer than those of the outer couples; all the setæ are in parallel rows (fig. 24). The nephridio-pores are difficult to view from the outside. Their arrangement is variable, but the majority are found outside of, or more lateral than the fourth row of setæ. The three anterior nephridio-pores are seen in front of setæ 4 (fig. 24). A more detailed description will be given further on.

Setæ. The ordinary setæ have been already described as sigmoid. There are two sacs of penial setæ attendant to each prostate, and opening in the same pore, but not in the same duct, as that organ. There is only one seta in each sac. This seta is sickle-like, much more curved than those in Deltania. The point is needle-like, and curved (figs. 122, 123). The very point is void of sculpture, but the part back of the point and up to the sac is sculptured as in the figure 123. The largest part of the seta is smooth, only showing the rings for the attachment of the muscles. The inner couples of setæ of the clitellum are somewhat raised, though otherwise not differentiated.

ANATOMICAL STRUCTURE.

The *body-wall* (figs. 114, 115, 116, 117, 118). The body-wall outside of the clitellum shows the usual sets of layers. The innermost vascular layer, which covers the longitudinal muscular layer, is very thick and prominent, though not very crowded with blood vessels (fig. 114). Under this layer, and between it and the longitudinal muscles, passes the spermduct, almost throughout its length, from the place where the two ducts unite to the one where they rise to join the spermduct. This layer is less pronounced anterior to clitellum, and appears absent in the vicinity

of the spermatheca and anterior to them. In the clitellar somites this vascular layer is especially prominent. The muscles of the longitudinal muscular layer in this genus, as well as in Deltania, are arranged in groups or projecting lobes, between which pass projections of the vascular layer, as well as transverse muscles in certain places. These lobes vary in width, and on the ventral side below the ganglion are arranged fan-like (fig. 103, *v. p.*), diverging from the median line. The longitudinal muscles are never arranged around a central axis, as is the case in so many lumbricides, though they show a faint trace of symmetrical arrangement. The zone of the transverse muscles is much thinner, five or six times narrower than the longitudinal zone (117).

The hypodermis is thick, with large, glandular cells of a flask-like or spindle-like shape. In the clitellar somites these glands become irregular, club-like, and project as far inside the layer of clitellar glands as the hypodermis is thick, or more (fig. 116).

The clitellum is developed only dorsally. The glandular layer is much thicker laterally and dorsally, tapering towards the ventral side, and ceasing entirely at a line drawn outside of the male papilla and parallel with the ventral ganglion. The glandular layer of the clitellum is very thin, and as compared with that of Deltania, about $\frac{1}{3}$ narrower. The cells of this layer are, however, very wide and long, there being generally eight or nine in the row. They are irregularly grouped in twos or threes, separated by narrow blood vessels, which, at rather regular intervals, are thicker. They are supplied with blood from sinuses situated between the transverse muscles, and which connect through these branches with a capillary network on the hypodermis (figs. 115 and 116).

Transverse muscles (figs. 118 and 119). There are numerous sets of transverse muscular bands in the clitellar somites, quite similar to those described by Benham in *Moniligaster indicus*. They are more numerous and prominent in the somite of the oviduct than elsewhere, and form there three distinct muscular bands the ventral ends of which terminate at the inner couple of setæ (fig. 119); the lateral ends again terminate on the lateral side of the body wall.

The posterior band is the smallest of the three and begins in the posterior and ventral part of the somite, in line with, but slightly posterior to the inner setæ, stretching from there diagonally across the somite, ending laterally at the seta 3 (fig. 119, *m* 1).

The next band is much larger and begins in the anterior part of the somite also in line with the inner setæ and stretches diagonally backwards ending posterior to but in line with seta 4 (fig. 119, *m* 2.) The third muscular band is of the same size and runs in the same general direction as the last, begins and ends in front of it, ending in front of the fourth seta (fig. 119, *m* 3.) A fourth muscular band of a somewhat similar character connects the posterior part of the oviduct with the body-wall terminating in front of the muscular band just described as *m* 1, on the figure (fig. 119, *m* 4.) Similar muscles as the oviducal one, are common in all earthworms,

connecting the various organs with the body-wall and require here no particular mention.

In the other clitellar somites we find bands of transverse muscles which stretch diagonally (fig. 118) across the body wall from the ventral part, almost immediately below the ventral ganglion, to the vicinity of the outer setæ. The ends of these muscles penetrate between the lobes of the longitudinal muscular layer (fig. 118, *l. m.*) These muscles are not continuous through the somite but are grouped in bands.

Ventral papillæ (figs. 120, 125 to 131). Argilophilus is readily distinguished from other California Eudrilidæ so far known, by its ventral papillæ, occupying the ventral side of the intersegmental grooves from the spermatheca to the segments next posterior to the clitellum. In *Argilophilus marmoratus ornatus* we meet sometimes with as many as 7 or 8 pairs, while in *A. m. papillifer* we find as high a number in a single median row, under the ventral ganglion. In no instance did I find a papilla on the segment itself, all invariably occurred rising from the groove between the somites, being in other words intersegmental. From cross-sections it will be seen that the papilla consists of two distinct parts, one exterior and lateral, consisting of elongated hypodermic supporting cells, which more or less fully enclose the interior main body of the papilla. This central part consists of larger or smaller gland-like bodies, varying in size and number according to the size and age of the papilla, etc. In some papillæ these bodies fill the larger part of the papilla, in others they are confined to the bottom or very center of the organ. As to the nature of these organs I am, as yet, somewhat in doubt, though they certainly must be considered as sensory organs of some kind. Stained with osmic acid the bodies present in sections a darker center, which appears of ganglionic nature, around which are grooped larger sacs which again are composed of smaller, light-refractive granules, giving the idea of a reticulated protoplasm. Numerous nerve fibres connect with those bodies, and evidently penetrate to the gaglionic center. Long tube-like cells butt directly on these glandulous bodies, while others grooped in bundles penetrate between them connecting with nerve ganglia. The transition between the supporting cells and the drainpipe cells of the papilla is sudden and not gradual. In fact the line of demarcation between the two is quite prominent. The supporting cells in the young papilla, entirely enclose the papilla, while in the larger and full grown papilla, they are pushed towards the side leaving the whole center to the drainpipe cells and the glands.

When stained with safranine the nuclei of the glandular cells become prominent, less so when stained with hæmatoxylon. The nuclei vary greatly in size and number. In some of the glandular bodies there are from one to three nuclei, in others none. In sections there are always less nuclei than divisions (cells?) apparently lying on the top of the reticulated mass. The nuclei may be seen directly above the nerve center, but generally they are found outside of it. It seems as if these glandulous bodies are modified agglomerations of hypodermic glands.

The arrangement of the glandulous bodies and the tube-like cells is very

regular, the former resembling small sugar-loaves standing in a row, with the fan-like arranged tubular cells between them (fig. 120). In some sections a bunch of nerve fibers is seen on either side touching the papilla, connecting on the other hand with the ventral ganglion. As to the nature of the papilla Dr. Michælsen suggests that a somewhat similar organ in *Acanthodrilus georgianus* is a taste or "Wollust" organ. It is, however, not unlikely that the minute light-refractive bodies are glandulous.

Many of the tubular cells contain a fine granulated secretion in varying quantities, which stain dark red with eosine. The fact that the whole papilla is concave in the center speaks also strongly for the glandulous nature of the organ. The figure of the "Augenapfela"-like organ of Acanthodrilus, given by Michælsen, may possibly have been taken from a young papilla in which the glandulous bodies had not yet developed. Organs of a somewhat similar nature have also been described by Horst from *Pontoscolex corethrurus* which, however, he does not figure in connection with nerve fibres. It is not improbable that all the sensory organs in the genital somites of the higher Oligochæta are of an analogous nature. Among such organs would be included the tubercula pubertatis, the puberty grooves, as well as some other epidermal structures in Heliodrilus, Hyperiodrilus and Eudrilus described more in detail by Beddard. However all the organs require re-examination by the aid of other methods, as one single method of staining will not suffice to reveal their true nature.

Septa (fig. 86). The anterior septa are greatly pouched, generally to such an extent that in cross-sections the various organs appear to lie several somites further back than they really do. Thus the gizzard and the posterior spermatheca may be seen in the same cross-section and this is also the case with the oviduct and the sperm-sacs. This pouching is principally restricted to the septa 5 to 13. These septa are also slightly thickened especially those bounding somites viii to xi.

Nephridia (figs. 59 to 77). The position of the nephridio-pores places Argilophilus very close to Plutellus. There are one pair of nephridia in each somite as usual. The first pair of nephridia are found in somite ii and others follow in all the posterior somites. The first five or six nephridia are somewhat larger than the others and open in front of the fourth setæ. All the following open irregularly in front either of the third or fourth setæ, or in the space between and anterior to them, or even outside of, or more lateral than seta four. Those which open laterally of seta four do not even open in the same row, as we find one nephridio-pore say as far out laterally from the fourth seta, as that seta is distant from the third, while others are half-way or one-third of the way between the fourth seta and the most lateral nephridio-pore. There is no regularity as regards this succession, though rarely two successive nephridia open in line behind each other. For instance, one nephridium opens in front of seta 3; the second as far outside of 4 as 4 is distant from 3; the third nephridio-pore is in front of seta 4, the following half-way between seta 4 and the most lateral pore, the following $\frac{2}{3}$ of the distance from seta 4 to the most lateral pore, the following in front of seta 4, the following again $\frac{2}{3}$ of the distance from seta 4 to the most lateral nephidio-pore, etc. (Fig. 124 *np. p.*)

The structure of the nephridium is considerably complicated. The nephridiostome, found in front of the ventral setæ, is unusually minute, and leads to a comparatively short duct, which connects with the body of the nepridium proper, at the point where the single-tubed outlet leaves the folds. This tube is not convoluted (fig. 59 (1)), but almost straight, very hard and solid, widening toward the base. When it reaches the folds it does not at once enter a tube, but forms a long, cylindrical, spongy mass (fig. 63), which extends the whole side or one-third of the length of the nephridium, before it assumes the proper shape of a clear canal (fig. 59, (2) to (7), and fig 64). In the beginning at (2), this mass shows no regular lumen, but a number of irregular pores and tubes, which might best be compared to the inner canals of a common washing sponge (fig. 64, (3), (2), (15)). In the center of this mass are imbedded the two parallel folds of the main nephridial canal (fig. 64, *a* and *b*). At first the spongy tube is located principally above the two canals, but soon the mass is shifted and the canals become imbedded in the center of the mass, or very nearly so (fig. 64, (3) to (5)). The small connecting tubules at (2), which were at first so irregular, soon assume a greater degree of regularity at (3), while at the same time two longitudinal lumens are formed—one on the upper (u) and one on the under side ((1), fig. 64) of the two central canals (*a* and *b*). At first these canals (u) and (1) are indistinct and irregular, but soon they assume the character of regular longitudinal canals (from (4) to (5), (6) and (7)). From (3) to (5) these canals (u) and (1) are connected by the transverse tubules, which completely surround the two central canals (a) and (b). At (5) the lower canal (1) becomes narrower, and the transverse ducts drop into the main canal (b), while the former lower canal (1) assumes the character of a rather thick, epithelial lining. The general effect of this arrangement is, that, seen with a lower power, the spur between (3) and (5) appears to consist of four distinct parallel canals, while from (6) to (13) the fold contains only three parallel canals. At (9) these canals become very crowded, the whole fold being narrower. The length of this narrower part varies, but generally already at (10), or shortly before entering on the bent plexus at (13), the fold has regained its original width. At (13) the canals turn; that is, (a) connects with (b) and the central canal folds upon itself, and for a short distance we have four almost parallel canals. At (13) the formerly central canal (from (8) to (11), (12) and (13)) leaves the lobe and crosses over to the other fold, and at (15) becomes the original canal (a), which runs its course all through the two folds, at (7) turning downward, becoming the lower canal, which again at (12) becomes canal (b), from there on pressing backward and again forward from (7) to (15), at which point it separates itself from the fold, and, running along the inner body-wall, forms the outlet duct opening at the exterior pore at (16). The connecting bridge between the two main folds, or rather between one fold and the free lobe of the other, between (14) and (15), is very narrow at (17), suddenly increasing at (14), gradually tapering toward (15). As regards the ciliation of the canal, it may be stated that it does not extend all through the tube. It appears that the canal is ciliated at places where the passage of the excretions is difficult. The narrow duct from the funnel to (15) is ciliated as well as the funnel itself. Again, the ciliation

begins at the point of recurrence at (7), but ceases after the duct has assumed its straight course at (8); it begins again at (10), and is with a certainty found between (15) and (17), and possibly between (17) and (12), where, however, I am not quite certain of its presence. The whole nephridial fold is imbedded in a wing-like cellular and fibrous mass, which at either end becomes thicker, supporting large pellucid peritoneal cells, such as found in the nephridia of many Oligochæta (fig. 64, *per. c.*), and a complex system of blood-vessels, which branch and form capillary loops partly on the folds, but principally between the spongy tubes and the two central canals (figs. 59, 63, 64, 67, *bl.*). The blood-vessels originate from a branch of the ventral vessel as in Lumbricus.

Scattered over the peritoneal cells are masses of free cells, generally agglomerated in separate heaps. Each cell is deeply crenate, as if it consisted of several individual cells, but in each such small agglomeration there is only one round nucleus (fig. 80).

If we recapitulate, we find that the nephridum of Argilophilus consists of the following distinct part from the nephridio-stome to the nepridio-pore:

1. Nephridio-stome, engaged in the anterior septum.

2. Narrow duct, which connects the nephridio-stome with the body of the nephridium proper, especially with the spongy tubules.

3. Spongy tubules, which are at first irregular, but which soon fuse into one main-tube with many branching tubules.

4. Main nephridial canal, which, recurring on itself several times, forms two distinct folds and one spur. The posterior fold contains besides the tube and tubules two turns of the canal, one of which is recurring. The anterior fold contains three turns of the canal, two of which are recurring. Part of this anterior fold disengages itself from the main nephridial mass and forms the

5. Spur. This spur contains four canals, two of which are recurring, the point of recurrence for all four being at the distal end. One of the recurring canals of the spur is connected with the posterior fold by the

6. Bridge, a part of the canal much narrower than the other, spanning the distance between the two folds.

7. The wide duct leading to the nephridio-pore, directly connected with the recurring canal of the posterior fold. In different nephridia this wide duct is of varying length.

8. Nephridio-pore, apparently without urinary bladder or collar.

9. A large wing-like, but rather thin, mass of peritoneal cells.

10. A complicated and extensive system of capillary blood vessels on the various parts of the nephridium.

Compared to the nephridium of Lumbricus as described by Benham we find a few more important differences, especially in the post-septal part. Thus the post-septal part of the narrow tube after reaching the first loop assumes the shape of a

tubular network, which only gradually fuses itself into one duct with numerous branching ductules, while in Lumbricus the single duct continues through the different lobes and in recurring winds around itself. The tubules in Argilophilus embrace the two tubes but cease after leaving the first fold. The muscular duct which is so prominent in Lumbricus is not represented in Argilophilus, but is replaced by an elongation of the single wide tube corresponding to the "wide tube of the 3d lobe" in Lumbricus.

Compared again with the nephridium of Deltania, we find that the principal difference consists in the absence of the urinary bladder and the collar at the nephridio-pore as well as in the absence of a cœcal bladder. The irregular or alternate locations of the nephridio-pores distinguish Argilophilus and Plutellus from all other earthworms, as far as known.

Alimentary canal (fig. 87 to 92). The *buccal cavity* is, as has been stated, greatly eversible, and generally remains everted after the worm is dead. The *pharynx* is only developed superiorly though there is a slight thickening of the lower wall of the buccal cavity at the junction with the œsophagus, at which place numerous muscles are seen to connect with the lower part of the body-wall. The pharynx is as usual furnished with numerous salivary glands (fig. 86, *sl. gl.*), extending from the vicinity of the brain to the posterior part of somite iv, the most posterior glandular mass being the largest (fig. 86). The various glandular lobes offer some characteristics, which if carefully noted and compared may be found to be constant enough to serve as species characteristics.

The *Œsophagus* begins in iii and occupies somites iii, iv and v, (fig. 86, *A. œ.*) forming first a narrow tube, which widens out, and rising upwards connects with a very large gizzard (*gz.*). This *gizzard* occupies in reality only somite vi, but its great length causes it to push far backward to such an extent that it actually occupies the space covered by viii and sometimes by ix. The gizzard is compressed from above, but widened laterally which makes it appear very much larger when viewed from above than when seen in vertical section. It connects posteriorly, in vii, with a very long narrow *tubular intestine*, which extends to somite xii, but which in somites xiii to xv is strongly nipped by the septa and considerably enlarged (fig. 86, *s,*) without, however, being strictly sacculated.

The *sacculated intestine* proper, however, begins first in xvi, and is much wider than the other part of the alimentary canal. The structure of the pharynx offers nothing of unusual interest. The wall of the gizzard contains the usual layers, but they are poor in blood vessels. The longitudinal muscular layer is thickest, and on the widest part of the gizzard it is five or six times as thick as the epithelium, gradually diminishing in size anteriorly and posteriorly (figs. 86, 87, 88, 89).

Pear-shaped or *Chylus Chambers.* Beginning immediately behind the gizzard, and extending throughout the tubular intestine, we find imbedded between the epithelial folds numerous pear-shaped organs of doubtful function. In pronouncing

these as chylus chambers, I do so with much hesitation, as I am not at all satisfied but that instead of being organs of absorption, they may not in reality be organs of discharge, or in other words, glands. I found these chambers always empty, appearing entirely transparent in sections of the intestine, and they never stain, apparently showing a want of contents, though this may be a temporary condition, owing to the state of the worms when killed, at which time these organs may have happened to have been temporarily empty. As regards location, they are found principally in somites vii to xii, and seldom extend further back than that somite. It is to be remembered that in somite xiii the tubular intestine changes its form and becomes considerably sacculated. In somites vii to xii this tubular part is very poor in blood vessels, or rather in large blood sinuses, while in xiii these sinuses begin to appear in large number and of large size. Thus, with no blood sinus in the epithelial folds, there are many pear-shaped chambers, while on the contrary, the cessation of pear-shaped chambers is accompanied by numerous and large blood sinuses (fig. 93). The pear-shaped chambers are imbedded between the epithelial cells, and probably all of them reach the inner cavity of the alimentary canal, though, from the sections made, this is not quite evident. Some of them, however, do, as will be seen from the figures 90 and 91. They are unequally distributed; in some places they fairly crowd out the epithelial cells, as in fig. 91, which is drawn from a longitudinal section, showing an unusually large number. Fig. 92 represents a surface view where they are less numerous, and fig. 90 represents a camera drawing from a transverse section of the gut. Each chamber consists of six, seven, or, in some instances, of only two or three cells, arranged as the clefts in an orange, around a central pore or short tube, which, however, does not extend all through the papilla, but ends blindly. At the lower end these individual chambers connect with numerous smaller and more irregular cells, which join each other close to the transverse muscular layer. The small central pore stands frequently in connection with the alimentary cavity. In the smaller and inner chambers this pore is less pronounced or entirely wanting. At the base of the chambers are seen a number of small glandular masses, with grainy and opaque contents (fig. 90 *gl.*). As regards the distribution of the chambers among the epithelial folds of the same somite, it may be noted that they are principally numerous in the dorsal and ventral regions, disappearing in the lateral regions (fig. 133, *ep.* and *c. r.*). This is the case in all the somites where these chambers appear in the tubular intestine. Chylus canals have been described by Michaelsen as present in the intestine of Enchytræus, but the difference between their structure and those of Argilophilus is quite great. In Enchytræus these canals are principally intercellular, and connect with bloodvessels or sinuses, while the pear-shaped organs in Argilophilus are extra cellular, and occur in parts of the intestine especially poor in blood vessels. The impossibility to procure fresh worms will necessitate a closer study of these organs, to be deferred to a more opportune time.

Typhlosole. The typhlosole and typhlosolar region is small, and not especially pronounced in front of and in the clitellar somites. Anterior to somite xix the

typhlosolar vessel, which is entirely dorsal, is many times smaller than the longitudinal dorsal vessel, but posterior to that somite the typhlosolar vessel assumes a larger size, almost equalling the main dorsal vessel. In the anterior somites the typhlosolar region does not project down in the intestine, but is only somewhat wider than the balance of the intestinal wall. The typhlosole in this part appears to be filled with a fibrous and spongy mass, in which, however, I have seen no distinct nuclei (fig. 134, *c. v.*). These cavities are more oblong at the walls, more round or angular at the center, where several larger cavities are seen. At the upper margin of the typhlosole this fibrous body gives room to two large and several smaller longitudinal canals, one at each extremity of the typhlosole, all separated by muscular fibers or cell-like chambers. In fig. 136 the fibrous nature of the interior of the typhlosole is somewhat more pronounced than it should be, the fibers appearing rather more regular than in reality, though the appearance is always as if the majority of the fibers radiated in a fan-like way from the central spongy mass. This part of the posterior typhlosole is in cross-section deltoid, with the point projecting into the cavity of the intestine (136, *ty*). The size of the typhlosole varies with the individual specimen.

Spermatheca (figs. 81 to 86). There are two pair of spermathecæ in viii and ix opening in the intersegmental grooves between vii and viii and viii and ix. The spermthecal pores are found in front of and slightly outside of the second setæ. As regards the size the spermathecæ may be said to be very large, but unequal, as we seldom find two of the same size. One or two are generally developed at the expense of the others and fill all the available space in the somites, frequently pushing the septa into the nearest somites. Seen in a transverse section of a segment the larger spermatheca may be occupying as much as three-fourths of the cavity (fig. 86). The spermatheca consists of two distinct parts, of which the upper is by far the largest, rounded in outline or potato-like with comparatively thin walls (fig. 82 *a*). This part, though somewhat warty, carries no diverticula and there are no smaller cavities for the storing of the spermatozoa. The lower muscular part is twisted, and set obliquely to the former, but can in no way be said to form any kind of a diverticulum (figs. 81 and 82). The muscular layer, which is a direct continuation of the longitudinal layer of the body-wall, is only arranged in one way forming a circular muscular stratum of the spermatheca much thicker at the base than at the top (fig. 82 *l. m*). This muscular layer extends to the upper part of the spermatheca (82 *a*), but is here quite narrow. The inner glandular layer is singularly well developed (figs. 82, *gl. e.;* 84 *gl. ep.* and 83), projecting inwards in large folds like the epithelial folicles of the intestine.

Secretions accumulate as a large whitish mass in the upper part of the spermatheca, and are seen to be sparingly mixed or streaked with spermatozoa. But the most characteristic part of the spermatheca is the interlacunary system for the storage of the spermatozoa in the lower or muscular part. A section of this part shows (figs. 82, 83 and 84, *l.* s.) a row of chambers imbedded between the epithelial cells, or between them and the muscular layer, and which connect more or less directly with the cavity of the spermatheca by means of narrow passages (fig. 83 *p.*) Some

of the chambers stand also in connection with each other as at 84 *sp. b.* and 83. In these chambers are stored the spermballs proper, one in each, rarely occupying the whole space of the chamber, but leaving considerable of the lacunary room empty, it never containing any free spermatozoa, only agglomerations or spermballs. These spermballs may also be seen as white opaque globules from the outside of the spermatheca as represented in figs. 81 *A* and *B*, *sp. b.*

Testes (figs. 94, 95, 96.) There are two pair of testes, one in somite x, one in xi, as usual post-septal. The anterior testes are enclosed in the sperm-sac, the posterior ones are generally free. Cross-sections show the testes to be deeply multilobed, with the lobes spreading. As regard the enclosing of the anterior testes it may be remarked that it is more or less complete, evidently depending on the size of the sperm-sac. In some specimens the testes were entirely enclosed, in others only the posterior apex was invested in the sperm-sac. In most specimens the testes were found pressed close to the body-wall and projecting backwards, the point of adherence to the anterior septum being immediately above and adjoining the ciliated funnel of the nephridium in line with the ventral setæ.

Sperm-sacs. There are three sperm-sacs, more or less but generally paired in somites x, xi and xii, the one in the latter somite being much more lobed than the anterior ones, and more frequently paired. The two anterior sperm-sacs are much the largest (fig. 96 and 97). They fill the whole somites, are not always paired, but the lobes connect all along the dorsal body-wall. The anterior sac closely invests the testes and ciliated rosettes in x and furthermore often encloses the ventral ganglion (fig. 96 and 97). The sperm-sac in xi is also often closed on the dorsal side, but it does not invest the testes nor the sperm funnels of that somite (fig. 98). The sperm-sac in xii differs from the other by being deeply lobed in the plane of the trabeculæ which are arranged in a fan-like shape from the alimentary canal. This sperm-sac which is seldom paired, does not extend below the alimentary canal as the anterior ones do, but so to say rests entirely on the intestine (figs. 86 and 99). The anterior sperm-sacs are also traversed by numerous trabeculæ, which however are irregularly arranged (fig. 100). The sperm-sacs are frequently infested with parasitic coccidiæ of round shape and with from one to three germ cells (fig. 100, *coc.*) In size the sperm-sacs are so large that they push far backwards, the one pair covering the other, the whole mass often reaching as far back as to touch the prostate, thus entirely covering the ovary and oviducts. This is especially evident in transverse sections when the ovary, oviduct and the three sperm-sacs may be seen at once.

The *ovary* is, as usual, found in xiii and offers no great peculiarities. It is generally deeply lobed, and in cross-section shows the same projecting lobes as the testes.

The *oviduct* is rather thin and characterized by a thick and long upper lip (fig. 103 *u. l.*), which generally is bent to one side. In one instance the upper lip was forked (as in fig. 103, *c.*). The muscle attaching the upper part of the oviduct to the body-wall is unusually strong (fig. 103, *m. s.*).

Spermducts and *prostates* (figs. 103 to 113). There are two pair of sperm funnels and ducts, the ducts joined together. The ciliated rosettes or sperm funnels are found in x and xi. The anterior pair is engaged in the sperm-sac of that somite (fig. 97), while the posterior pair is generally free (fig. 98). I have, however, seen the sperm-sacs attached to the funnels in these somites in some specimens, and there appears in this respect to be considerable variation; generally, however, the rosettes are free (fig. 98) in somite xi. Also with the anterior funnel there is some variation. In some specimens the funnels were entirely enclosed in the sperm-sacs, in others the sperm-sac was merely attached to the free surface of the funnel, while in others again one-half of the funnel was imbedded in the sperm-sac, while the other half was free. Figs. 97 and 98 show cross-sections with the sperm funnels or ciliated rosettes free or imbedded.

The *spermducts* join in xii and continue in a direct line to the prostate, which they enter in somite xviii. The point of junction is in the lower part of the glandular part close to the muscular duct (fig. 86, *e.*). The duct runs between the very thick vascular layer and the longitudinal muscular layer of the body (figs. 117 and 118, *sp.*). The two ducts are never fused together, but continue distinct and separate, though outwardly joined, as to the very entrance in the muscular part of the prostate (figs. 112 and 113). While the junction of the spermduct and the prostate is, to all appearances, in the glandular part of the prostate (figs. 110 and 113), the real point of entrance is in the muscular duct (fig. 113, *spd.*). After having touched the glandular part, the spermducts bend and cross the intervening space to the muscular prostate which they enter in a slanting direction, then passing considerably downward enclosed in the muscular part of the prostate, before entering the lumen proper (figs. 106, 107, 110, 111, 112, 113). Fig. 113 represents a cross-section in which the spermducts have been cut twice. Part of the spermduct is seen free close to the glandular part of the prostate, part again is seen just at the fusion of the ducts with the lumen of the muscular part. The duct closest to the lumen has been partly differentiated, the cells having lost their nuclei.

The *prostate* consists of a very large cylindrical, but greatly coiled, duct (figs. 106 and 107 and 1), which generally lies pressed flat to the body wall of xviii (fig. 86, *pr.*) It opens outwardly in xviii in the posterior part of the somite in the same pore as the penial setæ.

There are two layers of cells in the glandular part, but apparently no muscular layer between them. The outermost layer consists of large glandular lobes containing glandular cells which pass between the inner cell layer, and discharge in the lumen of the prostate (see figs. 108 and 109). There is a large system of blood vessels which penetrate both of the cellular layers, but which is not developed to the same extent as in Deltania.

In cross-section of the body-wall (fig. 103 *A*) the prostate is seen to open laterally to the penial setæ, though in the same pore, situated at the very junction of the glandular clitellum and the ventral zone (*v. p.*) of the body (fig. 103 *A. δ*).

Vascular system (fig. 86 *B* and 119). The following remarks on the vascular system can only be considered as preliminary, a more detailed report being reserved for a future study of living specimens. The main system consists of two longitudinal vessels, one dorsal and one ventral. There is no subneural vessel. Three pair of stout, oblong, thrice-contracted and sac-like hearts connect the ventral and dorsal vessels in x, xi and xii. The typhlosole has already been described.

The secondary vessels are characterized by numerous bead-like constrictions and swellings of the smaller branches, especially of those surrounding the funnels of the nephridia, and of the secondary vessels of the ventral longitudinal vessel.

Of the genus Argilophilus there are two rather distinct forms in California, which however, only differ externally, and, strange enough, have not, as a rule, been found in the same locality. Through careful dissection and sectioning I have not been able to distinguish any anatomical differences between the two species, though I have never seen any transitory forms as regards to the external markings. According to our present knowledge of earthworms we always expect to find internal specific characteristics of the species, and if such are not found we must hesitate to consider the respective forms as different species. Under such circumstances I will here refer to the two forms of Argilophilus only as varieties or subspecies, leaving to further investigations, if possible, to detect any internal differences.

Argilophilus marmoratus ornatus.

Figs. 125 to 129.

Argilophilus marmoratus ornatus Eisen, Zoe, iv, 253, October, 1893.

There are two rows of ventral papillæ between some of the somites in the vicinity of the clitellum, interior or posterior to it, or both. These papillæ are always more or less in line with setæ i, of rounded or slightly oblong form, and generally more or less of the same size. The number of papillæ varies, and frequently one papilla in a pair is wanting.

Habitat. I have found this worm only in the vicinity of Santa Rosa, Sebastopol, etc., north of San Francisco Bay. It occurs there in rich heavy soils, and constitutes the most common earthworm of the district. In the vicinity of Sebastopol I found this subspecies both in manure piles and in the wet, soggy places near the lagoon, places which part of the year must be covered with water from the slough or lake. Among several hundred worms collected in the month of May during one day, I found only one single specimen with median papillæ; all the others possessed lateral papillæ (fig. 125 to 128).

The *body* is thick, cylindrical, and only slightly tapering toward either end (fig. 132). As usual, the anterior segments are much wider than the post-clitellar ones. The prostomium frequently protrudes like an inverted sac hanging over the peristomium (fig. 130), as is probably the case with most genera of this family. While the anterior somites are well set off, the clitellar somites are less distinct.

though they can always be made out. The clitellum comprises somites xiii to xviii, though the posterior $\frac{1}{4}$ of xii is generally also somewhat thickened. Of the anticlitellar somites vii, viii, ix are thicker than the others, and as thick as the somites of the clitellum. All the somites are deeply segmented, except the clitellar somites and those anterior to iii. The external pores are situated as follows: Spermathecal pores, two pairs, between vii/viii and viii/ix, a little lateral of the seta 2. Oviducal pores in xiv in front of seta 1, generally in a slight depression, bordered by a swelling of the body-wall. The male pore and pore for penial setæ combined in one, open in line with seta 2 in xviii. The male pore is characterized by being situated on an elevated papilla more or less oblong. This papilla is surrounded by a circular depression which encroaches on the two adjoining somites (xvii and xix), and this depression is again surrounded by a lunar ridge, open ventrally, and extending from the center of xvii to the center of xix, thus reaching slightly outside of the clitellum (fig. 129). The clitellar glands do not extend further ventrally than to a line running from the center of the lunar ridge parallel to the setæ. The ventral part of the clitellum is depressed.

Ventral papillæ. One of the most interesting features of this genus are the intersegmental glands occurring on the ventral side and which in our present species are paired. They have possibly the same general function as the tubercula pupertatis of the true Lumbricids, or the ventral papillæ of Perichæta, etc., which latter they greatly resemble, but unlike the former they are variable in position, sometimes occurring to the number of as many as seven pairs. In other specimens again they are reduced to one solitary tubercle, situated on one side of the ventral median longitudinal line. The most common form is as follows:

One pair between viii/ix.
One pair between ix/x.
One pair between xv/xvi.
One pair between xvi/xvii.
One pair between xix/xx.

Other specimens possessed in addition to these pairs:
One between xx/xxi.
One between xxi/xxii.

To show the variability of these papillæ I give their places in a few individuals picked out at random, and I only add that other variations occur, as may be expected, from what is shown here. All these specimens were taken the same day and at the same locality:

No. 1. One pair, viii/ix.
One pair, ix/x.
One pair, xv/xvi.
One pair, xvi/xvii.
One pair, xix/xx.

No. 2. One pair, ix/x.
One single, xv/xvi, left side.
No. 3. One pair, ix/x.
One pair, x/xi.
One single, xiv/xv, right side.
One pair, xv/xvi.
One pair, xvi/xvii.
One pair, xx/xxi.
One pair, xxi/xxii.
No. 4. One pair, x/xi.
One pair, xv/xvi.
One pair, xix/xx.
No. 5. One pair, x/xi.
One pair, xix/xx.

The structure of these papillæ has been referred to in connection with the body-wall, and apparently does not differ in the two forms.

Argilophilus marmoratus papillifer.

Fig. 131, A and B.

Argilophilus marmoratus papillifer Eisen, Zoe, iv, 253, October, 1893.

The ventral side of the somites with one single median row of ventral papillæ, which are generally largest between the clitellar somites, diminishing gradually in size toward the anterior somites. The papillæ of this form are generally, but not always, more oblong than in the preceding form, where they are much more rounded. The clitellar papillæ are frequently diamond-shaped (fig. 131). The papillæ vary greatly in number and size in various individuals, but they are always median, never paired. Sometimes there are 6 to 7 papillæ posterior of the clitellum.

Habitat. This worm is very common in the vicinity of San Francisco Bay, south of Santa Rosa, where the former form begins. I have also this form from Santa Clara County, Monterey County, Fresno County, etc. It is common in the foothills of the Sierra Nevada, in Nevada County. Among many hundred specimens collected there was only one which possessed the paired papillæ of the former form.

Systematic position. The peculiar variation of the nephridio-pores places Argilophilus in undoubted proximity to Plutellus, both as described by Perrier and Benham. The extra chætal pores in Argilophilus warrants however the formation of a new genus, even if no other important characteristics would help to make it yet more distinct. As is well-known, Perrier's description of the ovaries, etc., in Plutellus have always been considered doubtful, and by Benham have been shown to be incorrect. This of course only in the case that Benham's worm really belongs to the same genus as the one described by Perrier. I do not doubt that this is so, because the positions assigned to the ovaries by Perrier is so abnormal that it is more

than likely that a mistake was made, as Benham has already pointed out. But on the other hand Benham's worm came from Queen Charlotte's Islands in the Pacific, while Perrier's worm came from the Atlantic Coast, many thousand miles away, and it will always be impossible to with certainty decide upon the position of the ovaries in Perrier's Plutellus until the original worm has again been investigated. That it will be found to entirely agree with the normal type I do not doubt.

From Plutellus our Argilophilus differs in several important points besides the location of the nephridio-pores. First, in regard to the number of the ciliated rosettes—in Plutellus only one pair, in Argilophilus two pair. One pair of sperm-sacs in Plutellus, three pair in Argilophilus. One pair of testes in Plutellus, two pair in Argilophilus. Four pair of small spermatheca in Plutellus, two very large ones in Argilophilus. Perfect clitellum in Plutellus in at least two somites, ventrally imperfect clitellum in Argilophilus. In other respects the two genera resemble each other greatly, and through the respective arrangement of the nephridio-pores, they form a distinct tribe or sub-family for which I propose the name *Plutellini*.

The following table will show the principal characteristics of the two genera:

	Argilophilus.	*Plutellus.*
Prostomium dovetailing the peristonium	Partly.	Completely.
Clitellum	Ventrally imperfect.	Ventrally perfect in at least two somites.
Nephridio-pores	In front of setæ 3, 4, and outside of 4; generally the latter, the arrangement being irregular.	In front of 3 and 4, alternating rather regularly.
Gizzard in	v.	vi.
Spermatheca	Two very large pair in vii and viii.	Four or five pair in vi, vii, viii and ix.
Sperm-funnel	Two pair in x and xi.	One pair in x.
Testes	Two pair in x and xi.	One pair in x.
Sperm-sacs	Three pair in x, xi, xii.	One pair in xi.
Ovary and *oviduct* in	xiii.	xiii.
Oripore in	xiv.	xiv.
Male pore in	xviii.	xviii.
Prostate	Very large, coiled, extending through several somites.	Straight, tubular, not very large, confined to one somite.
Nephridia commence in	ii.	iii.
Nephridial bladder at the entrance to the body-wall	Absent, the duct being single and straight.	Large, but of varying size in the two series of nephridia.
Ventral papillæ on the body-wall	Present in pairs or in a single one.	Absent.
Copulatory sets	Present.	Absent.
Typhlosole	A small typhlosole present.	No typhlosole.

PAPERS REFERRED TO.

Benham, W. Blaxland. An Attempt to Classify Earthworms. Quarterly Journal of Microscopical Science, vol. xxxi, pt. ii.

Benham, W. Blaxland. The Nephridium of Lumbricus, etc. Quarterly Journal of Microscopical Science, xxx, ii, 1891, 293.

Benham, W. Blaxland. Description of Three New Species of Earthworms. Proceedings of the Zoological Society of London, Feb. 16, 1892.

Beddard, Frank E. The Classification and Distribution of Earthworms. Proceedings of the Royal Physical Society, Edinb., 1891.

Beddard, Frank E. On the Earthworms collected in Algeria and Tunisia. Proceedings of the Zoological Society of London, January 5, 1892.

Beddard, Frank E. Some New or Little Known Oligochæta. Proceedings of the Royal Physical Society, Edinb., June 13, 1893.

Bourn, A. G. The Nephridia of Leaches. Quarterly Journal of Microscopical Science, vol. xxxiv, 592.

Eisen Gustav. California Earthworms of the family of Eudrilidæ. Zoe, a Biological Journal, San Francisco, California, vol. iv, No. 3, 1893, pp. 248–254.

Fletcher, J. J. Notes on Australian Earthworms. Proceedings Linnean Society of New South Wales, vii, 374.

Michaelsen, W. Oligochæten von Süd Georgien. Jahrbuch der Wissenschaftlichen Anstalten zu Hamburg, 1887. Hamburg, 1888.

Rosa, Dr. Daniele. I Terricoli Argentini, etc. Annali del Museo Civico di Storia Naturale de Genoa, ser. 2, vol. ix, 509, 1890.

Rosa, Dr. Daniele. Sui Generi Pontodrilus, Microscolex, Photodrilus. Bol. Musei, etc., di Torino, No. 39, vol. iii, 1888.

Rosa, Dr. Daniele. Microscolex Modestus. Bol. Musei, etc., di Torino, No. 19, vol. ii, 1887.

EXPLANATION OF THE FIGURES.

DELTANIA ELEGANS, Figs. 1–20.

1. A medium sized worm, natural size.
2. The anterior part magnified, seen from the ventral side, to show arrangement of setæ and the exterior pores of various organs. *p. n. p.* the first three pepto-nephridio-pores in somites ii, iii and iv. *n. p.* nephridio-pores of the following somites, opening in front of the 3d setæ, the pepto n. p. opening in front of the 4th setæ. *o. p.* ovipore. *s. pd. p.* spermiducal pore.

   In order to show the outer setæ, the body has been slightly flattened out. In reality the outer setæ should be slightly more dorsal than what appears.
3. The prostomium with somites i and ii.
4. Schematic view of the arrangement of the setæ on both sides of the male pore. The italic numerals indicating the order of the setæ, the roman numerals indicating the number of the somites.
5. The interior of the ventral surface of the genital somites viewed from above, showing the arrangement of the generative organs, etc. *spth.* spermathecæ. *c. r.* ciliated rosettes. *sp. s.* sperm-sacs. *sp. d.* spermducts. *ov.* ovary. *od.* oviduct. *p. s.* penial setæ and sacs. *pr.* prostate. *v. gl.* ventral ganglion. *t.* testes.
6. Longitudinal section of the anterior part of the body. The posterior section is a little more eccentric than the anterior. *br.* brain. *sl. gl.* salivary glands. *s. gl.* septal glands. *phx.* pharynx. *s. plx.* sigmoid plexus of the œsophagus. *sp. s.* sperm-sacs. *h.* hearts. *dv.* dorsal vessel. *t. i.* tubular intestine. *s. i.* sacculated intestine. *pr.* prostate. *s. ps.* sacs with penial setæ. *v. gl.* ventral ganglion. *œs.* œsophagus. *spth.* spermatheca. *t.* testes. *c. r.* ciliated rosettes. *ov.* ovary. *od.* oviduct.
8. Prostate and male apparatus. *pr.* prostate. *sp. d.* spermduct. *p. s.* penial setæ and sacs. *ms.* longitudinal muscular layer of the body wall.
9. Oviduct in xiv and xiii.

10. One of the septal glands in somites vi, vii, viii and ix.
11. Ciliated rosettes.
12. Ovary.
13. Spermatheca.
14. Exterior male-pore and penial papillæ. ♂ male-pore. *p. s.* penial setæ and papilla.
15. Exterior view of the clitellum seen from the ventral side. *op.* ovipore. ♂ male and prostate pore.
16. One of the regular setæ.
17. Penial setæ from somite xvii.
18. Testis from somite x.
19. Nephridium from somite xv.
20A. Anterior nephridium from somite ii.
20B. A nephridio-stome from one of the posterior nephridia.

DELTANIA TROYERI, Figs. 21–38.

21. Diagramatic view of the regular arrangement of the setæ in several somites posterior to the clitellum.
22A. A medium size worm.
22B. The largest specimen.
23. The anterior part seen from above, showing prostomium and somites i, ii, iii.
24. Schematic view of the arrangement of the inner setæ in the region on both sides of the male-pore. *ovp.* ovipore. *p. s.* penial setæ. ♂ male-pore.
25. The outside of the male genital region. *f.* folds in the body-wall. *p. s.* penial setæ. *p. p.* penial setæ papilla. *pr.* and ♂ prostate and male-pore. *c. d.* cupshaped concave region or sucker near the male-pore. *c. c.* central cavity between the male-pores. *m. st.* place for missing setæ No. 1. *s. st.* seta No. 2. *p. m.* penial muscles, arranged fanshaped, connecting the male-pore with the intersegmental groove.
26. Longitudinal section of the anterior part of the body. *b. c.* buccal cavity. *phnx.* pharynx. *sl. gl.* salivary or pharyngeal glands. *br.* brain. *s. gl.* septal glands. *s. ple.* sigmoid plexus of the œsophagus. *sp. s.* sperm-sacs. *œs.* œsophagus. *t.* testes. *spth.* spermatheca.
27. Somewhat schematic view of the alimentary canal seen from above. *œs.* œsophagus and pharynx. *sl. gl.* salivary gland. *s. gl.* septal gland. *d. v.* dorsal vessel. *h.* hearts. *t. i.* tubular intestine. *s. i.* sacculated intestine.
28. Brain and ventral ganglion.
29. One pair of the septal glands (vi).
30. Spermatheca from ix. Side view.
31. Spermatheca seen from below.
32. Spermatheca seen from above.
33. Male apparatus. *pr.* prostate. *p. s.* penial sacs and setæ. *sp. d.* spermduct. *ms.* muscles of the body-wall.
34. Nephridium from somite xv.
35. Oviduct and ovisac, left side.
36. The same from the same individual, but from the right hand side of the ventral ganglion.
37. The same sac seen from above.
38. Detail of the same.
39. Arrangement of the setæ surrounding the spermathecal pores.

DELTANIA BENHAMI, Figs. 40–48.

40. Arrangement of the setæ surrounding the spermathecal and male-pores. The same proportion and scale as in the preceding figure.
41. Sperm-sac.
42. Spermatheca, left side.
43. Spermatheca, right side of the same individual.
44. Oviduct.
45. Prostate gland and penial setæ. *v. v.* blood vessel covering the prostate.
46. Alimentary canal. *phx.* pharynx. *sl. gl.* salivary glands. *s. gl.* septal gland. *œs.* œsophagus. *s. i.* sacculated intestine. *c. i.* contracted part of the intestine generally commencing somewhere between somites xxvii to xxxvi and continuing towards the tail. In the first six somites the contraction is generally much narrower than in the following.
47. The worm natural size.
48. The male papillæ on somite xvii, showing the projecting penial setæ. The upper shaded part is the clitellum proper which ends at the center of the somite in line with the male-pore.

DELTANIA ELEGANS, Figs. 49–56.

49. The lumen and cœcal part of the nephridium in transverse section to the body. *fl. c. c.* flask-like glandular cells of clitellum. *bl. v.* blood-vessels in the transverse muscular layer. *t. m.* transverse or circular muscular layer. *l. m.* longitudinal muscular layer. *l. n.* lumen of cœcal part of the nephridium. *i. l.* interior lining of the nephridium. *gl.* glandular outer layer of nephridium. *cal.* calculi projected by the nephridium. *gl. c.* glandular cells of the clitellum. *atr.* urinary bladder or large contractile (?) chamber near the exterior pore of the nephridium. *ms.* muscular layer of the nephidial duct joining the flask-like cells of the clitellum. *col.* collar of the nephridium forming the exterior pore and consisting of regular layers of large, almost rectangular cells.

50A. Section through the body-wall and the lower part of a nephridium in somite xviii, but posterior to the clitellum. *n. d.* nephridio-duct. *c. n.* cœcal nephridio-bladder. *l. m.* longitudinal muscles. *c. m.* circular muscles. *ep.* epidermis and cuticle.

50B. Section through the body-wall and the nephridial collar in a somite posterior to the clitellum, illustrating the large ganglion (?), below the nephridial collar. The section shows the beginning of the nephridial collar and the place where it joins the cœcal vesicle.

50C. Section closely following the former nearer the nephridio-pore, showing a larger part of the ganglion. *i. c.* interior chamber or tubule, probably opening into the nephridial cœcum. *c. b.* inner lining of the cœcal bladder. *m. b.* muscular layer of the bladder. *c. np.* collar of nephridium. *n. gl.* nerve ganglion. *l. m.* longitudinal muscular layer of the body-wall. *t. m.* transverse layer of the body-wall. *h.* hypodermis.

51. Lower part of the prostate and penial sac, section through the male-pore, showing the junction of one of the penial sacs with the prostate. *p. s. s.* penis sac with setæ. *p. s.* one of the penial setæ broken. *pr.* and *ps.* prostate and male-pore. *pr. d.* prostate duct.

52. Section through the male-pore, cross-section through the body-wall, showing junction of the two spermducts, and prostate, and one of the penis sacs. *sp. d.* spermducts. *j. sp.* junction of spermducts. *pr.* prostate. *j. sp.* and *pr.* junction spermduct and prostate. *s. ps.* sac of penial setæ. *j. pr.* and *p. s.* junction of prostate and penal setæ. *♂* male-pore. *ep.* epidermis. *c. m.* layer of circular muscles, body-wall. *l. m.* layer of longitudinal muscles, body-wall. *n. c.* nerve cord from ventral ganglion. *p. p.* penial papilla.

53. Section through the male-pore showing junction of the two penis sacs with the prostate. *ps.* the two branches of the penis sac with the penis sheaths and penial setæ. *pr.* prostate. *c. m.* circular muscles. *l. m.* longitudinal muscles. *♂* male-pore. *atr.* atrium, or junction between the penis sacs and the prostate.

54. Section through the muscular part of the prostate. *gl.* inner glandular layer. *m.* outer muscular layer. *blv.* blood-vessels and cuticle.

55. Section through upper end of prostate. *blv.* bloodvessels. *c. v.* vessels between the inner and outer layer of cells. *i. v.* inner capillary vessels, lining the inner surface of the prostate.

56. Section through prostate at the junction of the muscular and glandular part. *m. pr.* muscular prostate; other letters same as in Fig. 54.

57A. Section through intestine in somite xv. *ch. l.* chloragogic layer. *l. m. l.* longitudinal muscular layer. *v. l.* vascular layer. *blv.* blood-vessel of the epithelium. *ep.* epithelial layer.

57B. Section through intestine, somite xiv.

57C. Section through intestine, somite xvi.

58. Cross-section through the clitellum, showing the relative size of the various layers.

ARGILOPHILUS MARMORATUS ORNATUS, Figs. 59–130.

59. A nephridium from one of the somites posterior to the clitellum. * **0,** inner orifice or nephridio-stome engaged in the muscular dissepiment *d.* **1,** narrow duct connecting the funnel with the fold. *p. f.* posterior fold. *a. f.* anterior fold. *u.* upper part of the spongy duct, which at **15** stands in direct connection with the narrow tube **1**. *l.* lower part of the spongy duct gradually increasing in size towards **5**. *a.* upper main canal. *b.* lower main canal, both the upper and the lower being different ends of the same canal. *o. c. f.* point of recurrence. *p. c.* peritoneal cell covering or support of the nephridium. *n. p.* nephridio-pore. *c. t.* capillary tubules of the spongy duct. *bl.* blood-vessels. *cap.* capillary blood-vessels surrounding the canals *a* and *b*. **1** to **17** mark places from which the detail drawings are taken. The nephridium is longer in proportion to its thickness than what is shown in the figure. If the part between the two parallel lines at **18** was increased to about one-third or one-fourth the entire length of the nephridium the proportion would be correct. If the whole nephridium had been drawn the figure would have been too long for the plate.

60. Nephridio-stome, front view.

61. Nephridio-stome, side view.

62. Nephridio-stome, end view.

* Letters and figures in full-face type refer to those in rings on the plates.

63. Inner part of nephridium more highly magnified. The numerals indicate the same places as in Fig. 59. The letters are the same as in the above figure.

64. Part of the same more highly magnified in order to show the capillaries and their connection with the inner duct of the tube. *t. f.* tube leading to nephridio-stome. *a.* upper canal. *b.* lower canal. *i. l.* inner lumen of the duct which connects at *c.* with the capillaries. *c. t.* capillary tubes, longitudinal view. *c. t. c.* capillary tubes seen in cross-section. *sp. c.* spongy canal or tube directly connecting with the duct **1** and containing the capillaries. *o. c.* outer canal leading to the nephridio-pore. *c. br.* the narrow bridge connecting the two main folds. *p. c.* point where ciliation begins. *bl. v.* blood-vessels, connecting with capillary blood-vessels surrounding the two inner canals *a* and *b*; only a part of the blood-vessels are drawn. This figure was carefully drawn with camera lucida, though, on account of the minuteness and numbers of the ductules *c. tc.* and *c. t.*, it was impossible to delineate all, almost one-fifth having been left out in places where they crowded each other.

65. View of the spongy duct between **3** and **4** showing the inner canals *a* and *b* and the connecting ductules; letters indicate the same as in previous figures.

66. The same spongy duct near **4,** end view, and partly cross section.

67. The posterior fold as seen at **5,** the crosses + and × indicate the respective point corresponding on fig. 59, in order to show the direction of the tube, which is contrary to the one shown on fig. 59. *sp. t.* the spongy tube with the upper and lower ducts, connected by ductules *c. t.* *bl.* bloodvessels. *cap.* capillary blood-vessels, some of which surround the inner canals, others the outer fold. At the place marked with a × the ductules begin to connect the upper spongy tube with the lower main canal instead of with the lower part of the spongy tube, as at *c. t.*

68. A somewhat larger figure of the last taken at the end ×, where the lower part of the spongy tube has almost vanished and become bereft of its tubules *c. t.*, capillary tubes entering canal *b.* *c.* chambers on the central canal in the spongy tube, which send off tubules on the other side of the two main canals, and which also enter the canal. *b. l.* lumen of the spongy tube. In this and the previous figure will be seen how the tubules of the spongy tube shown in figs. 65 and 66 have been found forming a more regular lumen *l*, which in the next figure will be seen to emerge into or change to a regular canal.

69. Part of the upper fold at **7,** showing the tubules of the spongy tube to cease, the tube itself to become more regular, fusing itself in canal *b*. The arrows show the direction of the fluid or excretions from the nepridio-stome to the pore.

70. Diagramatic section of the main fold at the place where the capillaries of the spongy mass have ceased, and at the very point of the outer band marked fig. 59 *o. c. f.* The spongy mass surrounding the canals is now void of tubules.

71. View of the anterior fold at **10,** showing the inner ciliated canal—formerly the lumen of the spongy tube—and the two canals *a* and *b*, which are enclosed by a common glandular mass, a continuation of the spongy tube. The lower fan-shaped lines are possibly openings or valves in the tube, connecting with the glandular mass. As will be seen, the glandular mass is not continuous, but seemingly separated by lumens—*l*—which may prove to be canals connecting with the tube at the slits above referred to.

72. A part of same fold between **9** and **10.** The lumen is here void of cilia, and the glandulous mass is smaller

73. The main fold as seen at the narrow place **9.** *l.* lumen void of cilia. *a.* one of the canals *a* or *b* seen on the other side of the lumen. *bl. v.* bloodvessels surrounding the lumen and its glandular walls.

74A. Cross section of the posterior main fold taken at **3,** before the main central lumen in the spongy duct was formed.

74B. Cross section of the posterior duct at **7,** showing the blind ending of the tubules.

75. A longitudinal section of the fold at **5,** showing only one of the central canals.

76. The same, the under side of the lumen being in focus.

77. A longitudinal section near **3**; here also one of the canals has been cut away.

78. Peritoneal cells of the nephridial supporting covering from *p. c.* fig. 59.

79. The same, end view. *p. c.* masses of perigastric cells.

80. One of the perigastric cells more highly magnified.

81. One of the spermathecæ, exterior view.

82. Cross section of a spermatheca. *a.* upper sac-like part. *b.* lower muscular part. *m.* muscular layer of the sac-like part. *l. m.* longitudinal muscular layer of the body-wall. *c. m.* circular muscular layer of the spermatheca. *gl. ep.* glandular epithelium. *i.* inner cavity of the spermatheca. *sp. b.* sperm balls. *l. s.* lacunary system, or chambers for the storage of the spermatozoa. *s. m.* secreted mass with streaks of spermatozoa. *spz.* spermatozoa. *t. m.* transverse muscular layer of the body-wall. *spth. p.* spermathecal-pore.

83. A longitudinal section of the spermatheca more highly magnified, showing the lacunary system and its position to the epithelial cells. Letters as in the last figure.

84. Cross section of the muscular part of the spermatheca, showing the arrangement of the storage chambers occupied by sperm balls. Letters as in fig. 83.

85. One of the sperm balls more highly magnified. Of these never more than one occupies the same chamber.

86A. A somewhat diagramatic view of the anterior somite, composed from several sections, in order to show the location of the organs, their relative size, etc. *cl.* clitellum. *br.* brain. *c.* lower commissure of ventral ganglion. *phx.* pharynx. *sl. gl.* salivary glands. *œ.* œsophagus. *gz.* gizzard. *t. i.* tubular intestine. *s. i.* sacculated intestine. *nph.* cross section of the anterior nephridia in somites ii, iii, iv. The other nephridia are not shown. *sph.* spermathecæ. *sps.* sperm-sacs. *l. sps.* lobed sperm-sacs in xii. *ov.* ovary. *ovd.* oviduct. *c. r.* ciliated rosettes. *sp. d.* spermduct; the connection with the ciliated rosettes not shown. *t* male pore. *pr.* prostate. *p. s.* sacs with penial setæ opening in the same pore, but more ventrally than the prostate. *c.* the place where the spermduct enters the prostate.

86B. The body opened from above and the interior organs exposed to view. A partially diagramatic view. The dotted lines indicate the organs covered by others, and which could not be seen except by removal of overlying organs. Letters indicate as in the preceding figure.

87A. Diagramatic longitudinal section of gizzard.

87B. Diagramatic transverse section of gizzard, to show its compressed shape.

88. A part of the epithelium and muscular layer of the gizzard seen in longitudinal section. *ep.* epidermis. *ept.* epithelium. *l. m.* longitudinal muscles.

89. A transverse section of the gizzard. (Letters as in fig. 88.)

90. A transverse section of the alimentary canal adjoining the gizzard posteriorly. *t. m.* transverse muscles. *l. m.* longitudinal muscles. *ep.* epithelium cells. *chy.* supposed chylus chambers. *c. c.* chloragogic cells. *gl.* glands. *bl.* bloodvessels.

91. The same in longitudinal section. (Letters as in fig. 90.)

92. Surface view of the same, showing the arrangement of the chylus chambers. (Camera drawing.)

93A. Section of a part of the dorsal vessel in somite xvi. *m.* muscular layer. *bl.* blood clot. *c. c.* chloragogic cells.

93B. Section through the alimentary canal in somite xiv.

94A. One of the testes.

94B. Right testis in cross section.

94C. Left testis in the same somite xi in cross section.

95. Ovary.

96. Section of the body in somite x, through testes.

97. Section of the body in somite x through the sperm funnels, very close to the septum.

98. Section through somite xi.

99. Section through somite xii. *sps. x.* sperm sac in x. *sps. xi.* sperm sac in xi. *sps. xii.* sperm sac in xii. *m.* longitudinal muscles connecting various organs with the body-wall. *i.* intestine. *d. v.* dorsal vessel. *v. v.* ventral vessel. *h.* hearts. *t.* testes. *v. gl.* ventral ganglion. *s.* septum.

100. Part of the sperm-sac. *coc.* parasitic coccidiæ.

101. One of the sperm-sacs separated.

102. Oviduct *a* and *b*, front view. *c.* side view of an abnormal oviduct with two, instead of one, upper lips. *u. l.* upper lip. *s.* septum. *m.* muscular band.

103A. Cross section of the body-wall through the male-pore, showing sections of prostate and penial setæ. *pr. gl.* sections of glandular part of prostate. *pr. m.* muscular part of prostate. *p. s.* penial setæ and their sacs. *v.* vascular layer of the body-wall. *l. m.* longitudinal layer of muscles. *t. m.* transverse layer of muscles. *c. gl.* glandular layer of clitellum. *h.* hypodermis. *g.* ganglion. *v. p.* ventral part of the worm.

103B. Detail of former, nuclei in the muscular part of the prostate.

104. One of the ciliated funnels freed from the attached sperm-sacs.

105. Diagramatic section through prostate, showing relative size of spermducts where they join the prostate.

106. Diagramatic representation of the prostate, showing its natural position when the body-wall is spread out. *pr.* glandular prostate. *spd.* spermduct. *p. s.* penis-sacs. *m. pr.* muscular prostate. *v. l.* vascular layer. *v.* ventral side.

107. Detail of the above, to show junction of spermduct and prostate.

108. Cross section of prostate. *bl. v.* blood vessels. *o. gl.* outer glands or prostate proper. *i. gl.* inner gland or atrium.

109. Detail of the former, showing the way the outer glands open into the atrium between the inner cell layer.

110, 111, 112, 113. Successive sections through prostate and spermduct, illustrating the junction of the two. In the first figure the spermducts have not yet entered the muscular part of the prostate. In the three following figures this junction is progressing, and finally almost accomplished. *i. m. l.* inner epithelium of the muscular part of the prostate. *pr.* glandular prostate. *spd.* spermduct. *bl. v.* blood vssels. *m. l.* muscular layer of the spermduct. In 110 the spermduct has been sectioned twice, as it is here convoluted.

114. Cross section through the body-wall in somite xix. *v. l.* vascular layer. *l. m.* longitudinal layer of muscles. *t. m.* transverse muscles. *h.* hypodermis.

115. Cross section through clitellum. *gl.* glandular cells with fine secretions. *c. gl.* glands from the hypodermis projecting into the former layer. *bl. v.* blood vessels.

116. Detail of the former, illustrating the hypodermal glands, etc.

117. Cross section through body-wall, somite xii. Letters same as above, illustrating the arrangement of the longitudinal muscles. *spd.* spermduct.

118. Cross section through body-wall somite xvii, illustrating the transverse muscles.

119. Somite xiv laid open, illustrating the diagonal muscular band. *ovd.* oviduct. *s.* septum xiii/xiv. *ovp.* ovipore. *1. 2. 3. 4.* setæ. *m. 1. 2. 3.* diagonal muscular band, beginning and ending on the body-wall. *m. 4.* muscular band connecting the oviduct and septum with the body-wall. *n. f.* nephridio-funnel. *is. g.* intersegmental groove. *v. v.* ventral blood-vessel. *h.* ventral part of the hearts. *l. v.* lateral vessel spreading on the body-wall and supplying the nephridium. *v. g.* ventral ganglion.

120A. Cross section through one of the ventral papillæ of Argilophilus marmoratus papillifer. *t. c.* tubular cells butting on the central glandular masses. *c. gl.* supporting and protecting cells, with coarse grainy contents. *h.* common supporting cells of the hypodermal layer. *l. m.* longitudinal muscles. *t. m.* transverse muscles. *v. l.* inner vascular layer. *nf.* nerve ganglions, connecting the glandular masses with the ventral nerve ganglion. *o.* glandular papillæ with central nerve ganglia.

120B. The corresponding organ, or ventral papilla in Argilophilus marmoratus ornatus; letters indicate the same.

121A. Detail of the last figure showing the most lateral of the glandular masses. *o.* glandular masses with a central nerve ganglion.

121B. Detail of the same figure showing the most centrally located glands.

122. One of the common setæ.

123A. One of the penial setæ.

123B. The tips of the former more highly magnified.

124. A part of the body-wall viewed from the inner side. A semi-diagramatic figure illustrating the arrangement of the setæ and the nephridio-pores over a certain space. *1, 2, 3, 4,* the various rows of setæ. *np. p.* nephridio-pores, indicated by round circles. Two of the nephridia are drawn in order to show their position, as well as the relative size of the ducts.

125, 126, 127, 128. The anterior part of the body seen from the ventral side. Various specimens to show the variation in position and number of the ventral papillæ. *spth.* spermathecal-pores. *ovd.* oviducts. ♂ male-pores. The ovals indicate the ventral papillæ.

129A. The clitellar and some of the anterior somites, viewed from the ventral side, showing the various pores and the genital zone. Letters indicate the same as in the preceding figures. *p. s.* penial setæ protruding from the male-pores.

129B. The twenty-three anterior somites of a specimen killed in alcohol gradually increased in strength and hardened in strong alcohol, showing the spermathecal, ♀ and ♂ pores, the ventral papillæ, etc.

129C. The most anterior somites seen from above.

130. The two and three anterior somites of two different specimens, showing the inverted buccalic sac, the prostomium, etc. *a.* and *c.* ventral; *c. d.* and *f.* dorsal; *e.* lateral view.

ARGILOPHILUS MARMORATUS PAPILLIFER, Figs. 131–136.

131. The anterior somites viewed from below showing the single row of ventral papillæ, diminishing in size anteriorly. The outlines at the side represent the shape of the papillæ as found in the figured specimen.

132A. A medium size specimen preserved in strong alcohol. The specimen was first killed in an increasing solution of corrosive sublimate.

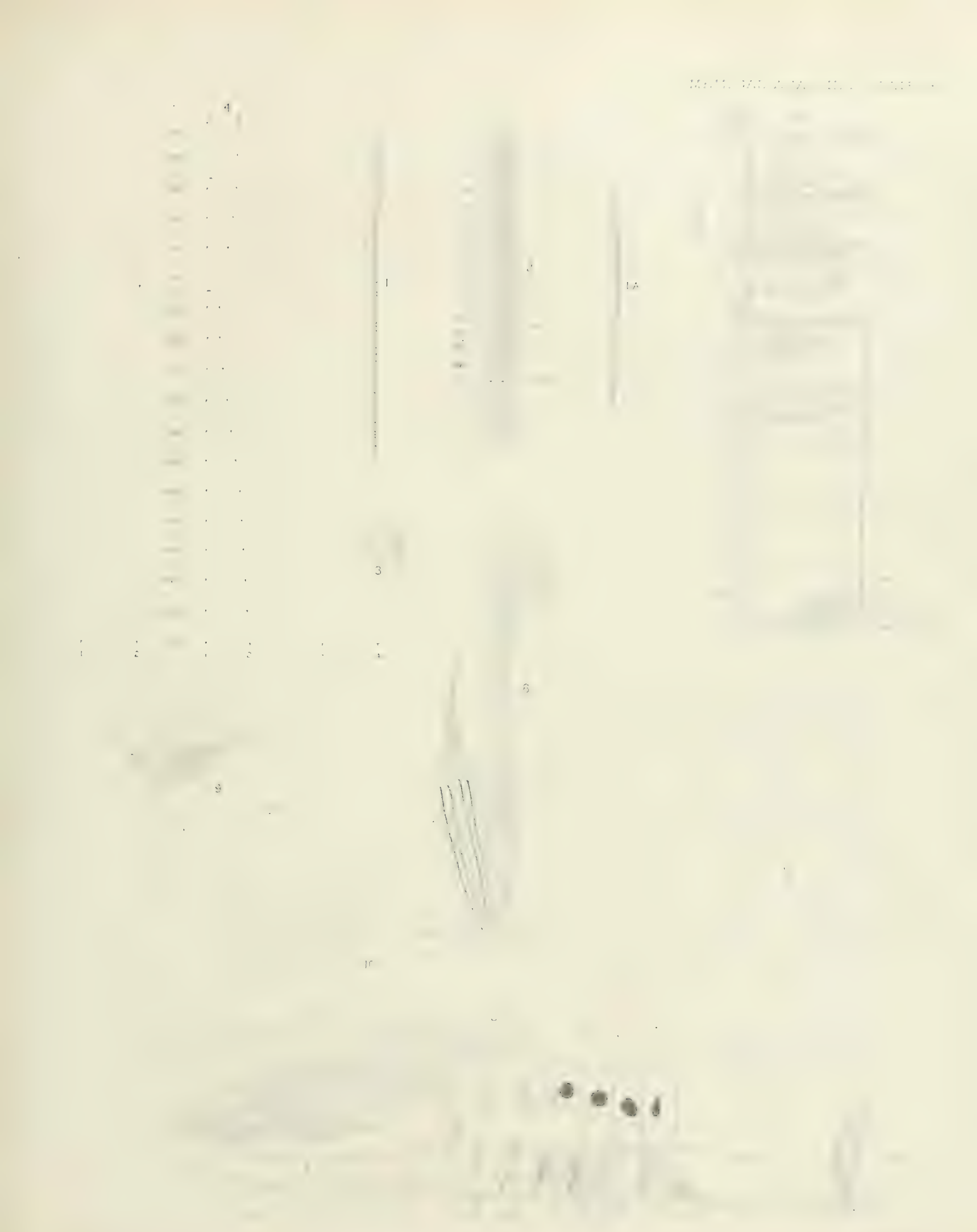
132B. A large specimen of the former figured while alive.

133. Section of the intestine and dorsal vessel in somite ix, in order to show the typhlosolar vessel. *t. v.* typhlosolar vessel in the intestine. *d. v.* dorsal longitudinal vessel. *ch. c.* chloragogic cells of the intestine. *e. p.* epithelial folds of the inner lining, void of chylus glands. *c. r.* the chylus region of the inner epethelial lining.

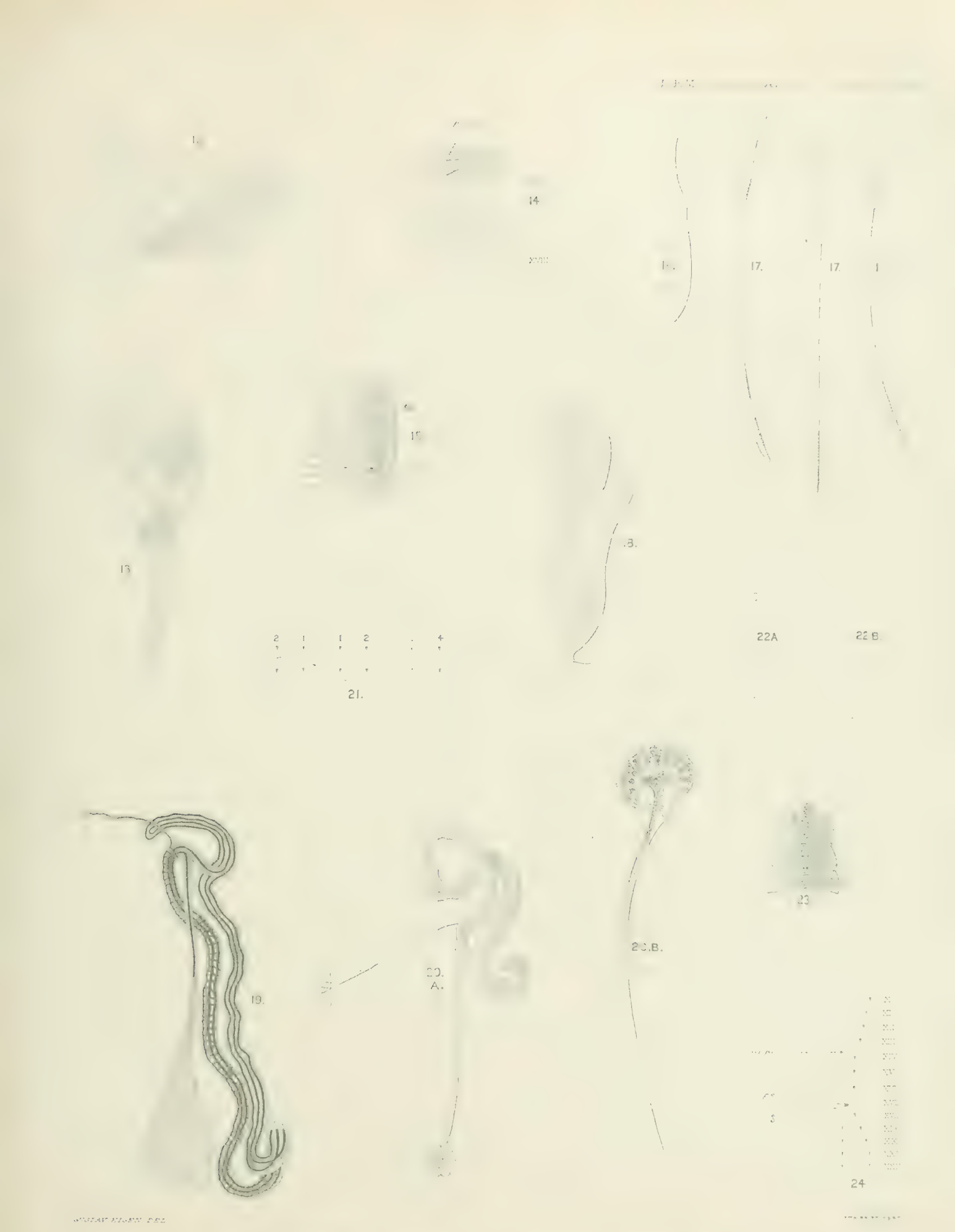
134. The typhlosolar region of the intestine, detail from the last figure more highly magnified. *t. v.* typhlosolar lining. *l. m.* longitudinal muscles of the intestine. *c. m.* circular muscular layer of the same. Other letters as in the last figure.

135. Cross section of the intestine and dorsal vessel in somite xxiv illustrating the typhlosole. *s. i.* sacculated intestine. *bl. s.* blood-sinuses. *ty.* typhlosole.

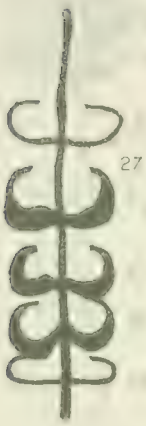
136. Detail of the former, showing the typhlosole proper, greatly magnified. *d. v.* dorsal vessel. *ty.* typhlosole. *bl. r.* blood sinuses in the intestine. *l. m.* longitudinal muscles. *c. m.* and *e. p.* circular muscles and epithelial lining of the intestine.



DELTAXIA ELEGANS Fig's. 1 to 11



DELTANIA ELEGANS PLATE 3 TO 20. MAY TORREY FIGS 1 TO 24



27

28

26.

30.

31.

29.

34.

32

33.

39.

46.

41

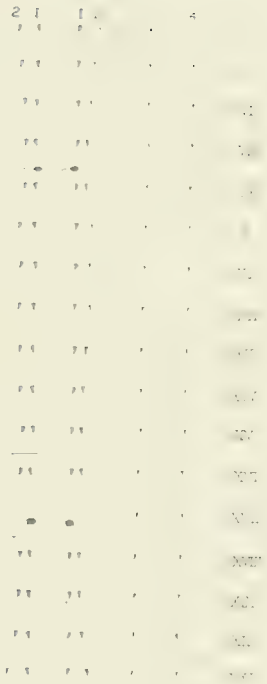
XV

36.

37.

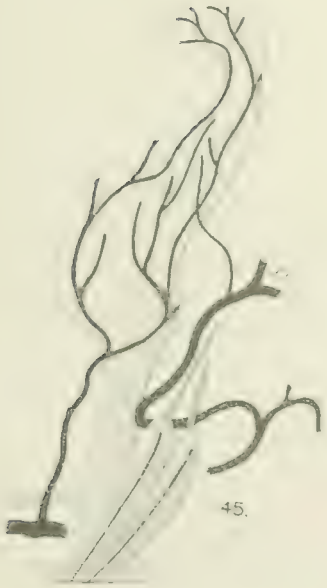
42.

38.



40.

43.



45.

XVI

47.

XVII

XVIII

48.

44

FIG'S

DELTANIA ELEGANS Figs. 1-5 PLATE 21.

61.B.

71
72
74a

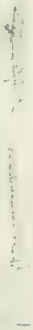
87.B.

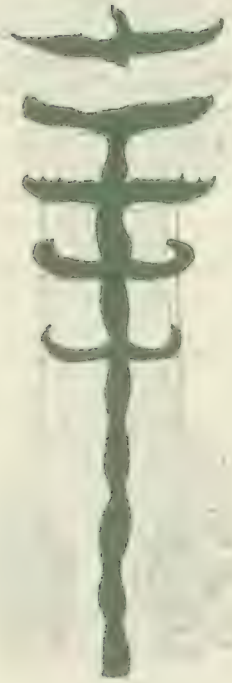
87.A.

86.B.

88.

86.A

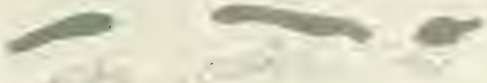




89.

91

90.



88 A.

94 A.

93 B.

94 B.

92.

95 B

95 A.

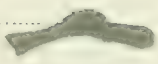
94 C.

Ar

96

99.

97.

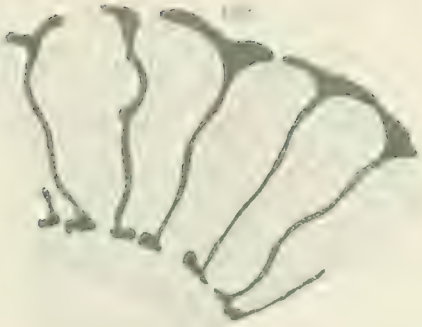


100.

98

101.

102 A
102 B.
107
106
105
103.B.
103 A



111

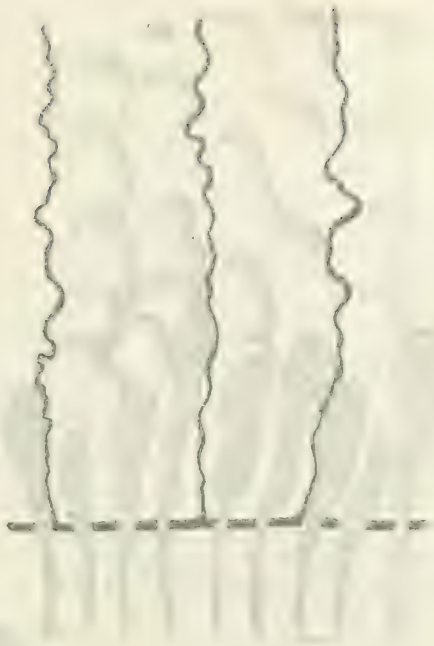
112

109

113.

110

114.



117.

118.

120.A

120.B.

119

121.B.

122

121.A.

123.B.

123.A.

124.

PHRIXUS MARMORATUS GENATUS Figs. 121 to 124

128A.

128B.

131A.

131B

131C.

ARGILOPHILUS MARMORATUS GRNATUS Fig's. 125 to 127

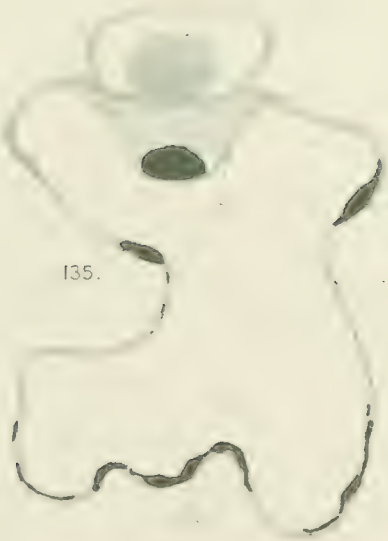
ARGILOPHILUS MARMORATUS PAPILLIFER Fig's. 131 & B.

133. A.

133. B.

134.

135.



136.

PACIFIC COAST OLIGOCHÆTA.

I.

Phœnicodrilus taste; Pontodrilus michaelseni; Eclipidrilus frigidus.

BY GUSTAV EISEN.

PHŒNICODRILUS nov. gen.

Small slender terrrestrial oligochætæ closely allied to Ocnerodrilus from which genus they differ only in the absence of a prostate. In Ocnerodrilus the organ known as a prostate, or by some as atrium, is a prominent and important characteristic also shared with such genera as Kerria and Gordiodrilus. These genera which form a natural group have been chiefly characterized by one or more prostates, opening either with or independently of the spermducts. Our present form resembles Ocnerodrilus in all principal characteristics which distinguish that genus from Kerria and Gordiodrilus, with the exception that it has not even a trace of a prostate. There are also some other minor characteristics as will be seen from the description, but with the knowledge of only one species it is yet impossible to know if these are genus or species characteristics. For the present the following genus diagnosis may suffice:

Small, terrestrial oligochætæ inhabiting damp soil.

Clitellum imperfect; comprises the oviduct and the male pore.

Spermathecæ with rudimentary diverticula at the inner free end—in ix. The spermathecal pore between viii and ix.

No differentiated penial setæ. The common setæ sigmoid, 8 in each somite in 4 couples.

Nephridia paired, those posterior of the clitellum surrounded by large peritoneal cells.

Alimentary canal without gizzard and typhlosole, but with one pair of large diverticula in ix, connecting with the tubular intestine in the posterior part of the somite. Four pair of septal glands in v, vi, vii and viii.

No subneural vessel. Dorsal and ventral vessel connected by hearts in x and xi. Lateral vessel projected anteriorly from each of the diverticula. Blood yellowish-red.

Testes two pair, in x and ix. Large sperm sacs in ix, x, xi, xii. Ovaries in xiii. Oviduct in xiv. Two pair of ciliated rosettes in x and xi. Sperm ducts not fused, open in the male pore in somite xvii. No prostate.

Phœnicodrilus taste n. sp.

The size is that of a very large Ocnerodrilus though even fully matured specimens varied greatly as to length. My largest specimens, which first had been slowly killed by dropping solution of corrosive sublimate in the water dish and then extended before being hardened with alcohol, reached $2\frac{3}{4}$ inches by $1\frac{1}{4}$ line in thickness at the clitellum. Average-sized specimens were considerably over 2 inches long. This refers to the mountain specimens collected in the Sierra El Taste; the lowland specimens from Pescadero were much smaller not reaching the 2-inch mark. The body is slightly tapering towards the tail end. The somites are well set, those of the clitellum are hardly distinct. The prostomium is not long, but broad, dovetailing the peristomium about one-half. From here on the somites gradually, though slightly, increase in size until somite x which is a little the largest, xi, xii and xiii are smaller. The somites posterior to the clitellum are slightly larger than somite x, except the last few posterior ones.

Clitellum comprises somites xiv to viii. Vertically it ends at a line drawn halfway between setæ 2 and 3, slightly receding in somite xiv. Strictly speaking the clitellum does not enclose the male pore, as the pore is situated more ventrally than the thick clitellar layer, and between that and the pore there is no connecting ridge or papilla.

An accessory copulatory swelling is seen around the outer couple of setæ in somite xiv (fig. 26, *c. c.*), the body-wall here being raised like a small mound, with the setæ slightly outside of its center, from which the cells are arranged as radii in a circle.

The male pore is surrounded only by a very small ridge or papilla, not high enough to be seen with a magnifying glass sufficiently strong to reveal the elevated papillæ of the oviducts. But the whole zone around the male pore is often considerably elevated, turned inwards or towards the median line of the body and rounded forming a longitudinal groove.

Exterior pores. The spermathecal pore is situated in the intersegmental groove between somites viii and ix, in front of and slightly outside of seta 2, the inner angle of the pore being in line with that seta, while the body of the papilla is situated more dorsally. The ovipore is situated close by, in front of, but not outside of seta 2. The male pore is situated in xvii exactly in a line with setæ 1 and 2 according to the longitudinal muscular fibres, but as the body-wall is slightly contracted in this somite the pore appears as if situated slightly more ventrally; the exact location is, however, the place left vacant by the absence of the ventral couple of setæ. This couple (setæ 1 and 2) are never, at least not in adult specimens, found developed in this somite, though the tips of the young reserve setæ are sometimes seen in their sac close to the pore.

Nephropores open in line with seta 2, and are situated in the anterior one-third of the space between the setæ and the anterior septum. The pores are large, round and easily distinguished.

Body-wall. The various layers offer nothing of great interest. The longitudinal muscular layer is slightly thicker at the dorsal part, and so is the part situated between the 3d and 4th setæ. The muscles in this layer do not show any feathery arrangement around a central fiber, but are irregularly distributed. There are no dorsal pores. The body-wall in somites xi and xii is thinner than the anterior somites.

Arciform muscles. The inner surface of the body-wall in somites xvii and xviii, and partially also in xvi, are covered with numerous arciform muscles which stretch transversely or diagonally across the body cavity, connecting the region running through the outer couple of setæ with that of the male pore and the inner setæ. The number of muscular bands in these somites is very great and they vary in length and thickness. There is also a slight variation in different specimens, the main fascicles being, however, always in the main the same. These muscles are best viewed when seen from above, the body wall being spread open and the sacculated intestine removed. As will be seen from the drawing, which is a careful representation of the principal muscular bands, most of the bands begin or are attached to the body-wall on a line running through setæ 1 and 2 and ending in a line running through setæ 3 and 4. But there are some which begin more ventrally and end more dorsally than either couple of setæ. In somite xviii most of the fascicles run in right angle to the median line, but the most posterior one as well as one or two more run diagonally backwards. In somite xvii there is one large group of fascicles beginning around the male pore and running transversely sideways, while another group of fascicles run diagonally forward connecting the male region with the anterior part of the somite. There are also longer fascicles anterior of the male pore which run much further sideways than the outer setæ. In somite xvi there are but few fascicles, much smaller and shorter. The male pore and spermducts are so entirely covered up by these muscular fascicles that they can only be seen with the greatest difficulty when viewed on the spread body-wall. In the figure (fig. 7), only the principal muscles of one side are drawn. The shaded bands which are seen crossing the median line are slight ridges in the body-wall, connecting the principal muscle fascicles. The objects of these muscles are of course to elevate and depress the male zone. Similar muscles were first described by Benham in Moniligaster, and later by myself in Argilophilus. They no doubt exist in most species of Oligochæta but are of great interest and value as species characteristics.

The *septa* begin between somites v and vi, and gradually increase in size toward somite ix. The most anterior septum, however, is not unusually thick. The following three septa are very thick, that between viii and ix being the thickest.

Alimentary canal. The buccal cavity is very large and occupies somites i and ii. Pharynx begins in iii or posterior part of ii and extends to the posterior part of iii. It is only developed superiorly and merely attached to the œsophagus in the posterior part of ii. Œsophagus consists of one in the beginning narrow and comparatively even duct, which in iv rises upwards and then becomes considerably sacculated

in somites v, vi, vii and viii, again to assume a more tubular form in ix. In the posterior part of this somite it is joined by the two diverticula. The tubular intestine proper occupies the two somites x and xi. In xii begins the sacculated intestine. The diverticula of the œsophagus are very long, narrow and slender, more so than in any species of Ocnerodrilus which I have seen. These exterior features offer nothing peculiar. The lateral blood vessels issue, as usual, from the anterior points of the diverticula.

These diverticula of the œsophagus originate in the posterior part of the somite, and not in the anterior part as in Kerria. The structure of these diverticula corresponds with that of the same organ in Ocnerodrilus. Only in that genus the rule appears to be that the interior of the diverticulum consists of one single chamber encroached on by a few parallel ridges. The diverticulum of *Phœnicodrilus taste* is in the central part four to eight chambered, divided off longitudinally, presenting the same appearance as an orange when cut through crosswise (figs. 14–16). The number of chambers varies, as in one specimen I found the right hand diverticulum to have four chambers, while the left one had five chambers. In sections near to either end these chambers fuse further and finally only two and one chambers are left.

But this fusion is unequal at the two respective ends. In the end nearest the junction with the alimentary canal there is only one chamber found, and a little further forward there are two chambers, the number increasing until generally eight chambers are found in the center. From there on no increase is made, but the chambers decrease in width, and at the anterior end suddenly fuse into one which is small and narrow, not thicker than a blood vessel. The longitudinal blood vesssels are very much the same as in Ocnerodrilus, but generally more in number.

The number of blood vessels in each diverticulum varies with the place where located in the diverticulum. The section nearest to the posterior septum of the alimentary canal shows the two laterals from the dorsal vessel entering the diverticula. To begin with, they are seen on the outside of the cellular mass of the diverticulum, while in succeeding sections they appear like a few blood vessels scattered on the outside of the epithelial cells. In succeeding sections these vessels are seen to increase in number until in the center of the diverticulum they number about one hundred.

The blood supply for these organs come from branches of the dorsal vessel and not from collective vessels from the alimentary canal.

Salivary glands are as usual found attached to the muscles of the pharynx, but they are smaller and less numerous than in Ocnerodrilus, the pharynx being less lobed and more compact than in that genus. These glands open through ducts, which follow muscular strands into the pharyngeal cavity in a similar way as will be more in detail described in Pontodrilus. In fact it is probable that all the suprapharyngeal glands in the respective genera of Lumbricids open similarly and without any great variation as to detail (fig. 18). The narrow ducts from the gland penetrate the pharyngeal epithelium and form at its outer edge small ovoid pockets for temporarily storing a small amount of the salivary secretion. These ducts end with the pharynx,

the œsophagal epithelium neither being furnished with ducts nor storage pockets (fig. 18).

The suprapharyngeal glands are posteriorly connected with the septal glands, not only with the nearest pair, but with all the pairs in the respective somites. In *Ocnerodrilus Beddardi* I called the attention to this fact, but I was not able to point out the connection between all the glands, which connection, however, I do not doubt really exists in all genera of this family, and probably in most other Oligochæta.

Septal glands (fig. 2). As regards these glands our present species offers no great peculiarities different from species of Ocnerodrilus generally. There are four pair which surround the œsophagus in the usual way in somites v, vi, vii and viii. The glands are considerably lobed (fig. 1–2), and decrease in size posteriorly. That is, the pair in v is by far the largest, the one in vi is smaller and so on, the one in viii being much the smallest. This gradual decrease in size posteriorly, though the most common one in this class of Oligochæta, does, however, not always exist in all species. I have one species yet undescribed from Guatemala in which all the glands are of the same size. In our present species the glands are distinctly paired, but they lie so close together that that they appear in each somite as one single gland surrounding the intestine. In sections the glands are seen to be abundantly supplied with blood sinsues or larger vessels.

These septal glands (fig. 2), connect one and all with the suprapharyngeal gland, being, so to say, superposed on several main longitudinal muscular bands connecting the pharyngeal glands with the body-wall in somite ix. Wide and narrow ducts follow these muscles, causing the secretions of the septal glands not to empty in the alimentary canal in the respective somites in the glands, but in the pharyngeal cavity as shown in fig. 18.

Fig. 2 is, as far as outlines are concerned, a correct representation of these glands from a section lateral to the œsophagus. Most details, however, are not filled out. The glands on the upper side are those above the œsophagus, the lower row again those below the œsophagus, both opening on the upper side of the pharynx.

The *setæ* occur in couples of two, as usual, the distance between setæ 1 and 1 being about the same as the distance between 2 and 2. The shape is the usual sigmoid one found in Ocnerodrilus, and the size is rather large. The free points are slightly corrugated. The setæ occur in all somites after the first, but there are never any developed setæ where should be the inner couples in xvii. Very small undeveloped tips may sometimes be seen close to and lateral to the male pore enclosed in the reserve bag, but even they are not always present.

The blood vessels agree in all respects with those of Ocnerodrilus. There are two pair of hearts, one each in x and xi and one pair of connecting vessels in ix.

Nephridia are found in all the somites except the first few anterior ones. In somites iii to v the nephridia are very small and dwarfed, but from there on posteriorly they increase in size. Those in front of the clitellum are not fur-

nished with a glandular covering of peritoneal cells; those in the clitellum show a few of those cells, while the nephridia posterior to the clitellum show a highly developed envelop of peritoneal cells, similarly as is the case in some species of Ocnerodrilus. In our present form the difference between the anterior and postclitellar nephridia is very marked, the latter ones being prominently visible through the body-wall both in alcoholic specimens as well as in alive ones. As regards the form of the nephridia, it agrees in general with that of the various species of Ocnerodrilus, some of which I have re-examined. The windings of the canals as well as the general arrangement of the ducts is much the same in the genera which I have examined more in detail, such as Ocnerodrilus, Kerria, Deltania, Argilophilus, Pontodrilus. Especially is this the case with Ocnerodrilus and Kerria, the nephridia of which have been misunderstood, in several particulars, especially so as regards the windings of the canals and the presence of blood vessels.

In Ocnerodrilus as well as in Phœnicodrilus the nephridium consists of two distinct parts, A, the folds, with the winding canals, and B, the peritoneal covering, with more or less numerous blood vessels. The peritoneal covering again is also divided in two parts, one upper almost free, and one lower surrounding or at least adjoining the canals, about which more later on.

In Phœnicodrilus the nephrostome leads to the narrow duct which connects with the folds of the main nephridial body. The folds of these canals are placed on the outside of or rather on the upper edge of the peritoneal covering. The narrow duct when it enters the fold is very narrow, in fact conspicuously so. In the neck of the nephridium it coils itself several times around the part of the wide duct that is enclosed in the neck. Retaining its narrow size it enters the anterior fold, in which it is the most anterior and exterior canal, but nowhere does it appear to ramify as in Pontodrilus, Deltania, Argilophilus, etc. It retains its narrow size all through the windings (fig. 12), but increases in size in the posterior fold, in which the three canals are of equal size.

In the apex of the spur, which as usual is thicker than the fold, the continuation of the narrow duct connects with the very wide canal which later on forms the bridge. After passing the bridge this wide canal becomes much narrower but still continues as thicker than the other canals until it enters the posterior fold. It is also less coiled than any of the other canals, in fact it is most conspicuous by being very straight—it always occupies the under and inner side of the folds. Even in the "windings," which, in this species, occupy a very large part of the folds, this canal is straight, while the two other canals are coiled and bent. We thus find in this genus all the principal parts of the nephridium of the much larger Argilophilus, and it may be safely stated in all highly developed Oligochæta the structure of the nephridia are in the main the same. As far as I am aware we may distinguish the following divisions of a perfect nephridium:

a. Nephrostomal part.
   Nephrostome, or funnel.
   Neck of nephrostome, consisting of glandular cells.
   Narrow, or nephrostomal duct.
b. Main glandular part.
   Neck of glandular lobe, connected with the nephrostomal duct.
   Anterior fold.
   The windings, or the coiled part of the two folds.
   Posterior fold, in which the three canals are of the same size.
   Spur, with four canals.
   Bridge, with only one canal.
c. Efferent part.
   Wide terminal-duct or outlet. The latter is frequently furnished with a cœlomic bladder.
   Nephropore.

When the nephridium is spread out and mounted in glycerine it is seen that the canals are of different transparency. Thus the wide canal coming from the bridge, together with its continuation in the spur, is much darker than the two other narrow canals, which are conspicuous through their brilliancy. These two white canals meet in the very apex of the spur, while the two darker canals meet a little further in. The greater obscurity of the wider canal is partly due to ciliation.

The nephrostome of *Phœnicodrilus taste* is furnished with a large neck, almost as large as the rosette, containing several very large cells with conspicuous nuclei. The nephrostome is about as long as the narrow tube.

In size the nephrostome ranges with the very largest, it being conspicuous and readily dissected.

The marginal cells vary in number between eight and fourteen. There is a larger central nucleus as usual. The glandular neck of the nephrostome contains two of these nuclei much larger than any of those found in the rosette, though it also contains several smaller ones. When the body of the annelid is laid open and viewed from above, the nephrostomes are seen to lie on their side as in fig. 9, the side of the thick rim of the rosette being uppermost. In order to see the rosette flattened out it is necessary to dissect out the nephrostome, which operation in this species is not particularly difficult, as the muscular tissues easily separate.

The peritoneal covering of the posterior nephridia separates itself in two distinct masses, one dorsal and one ventral, the latter being somewhat the smallest. At the point where they join the peritoneal covering has narrowed down to a narrow band connecting the two main parts.

The upper peritoneal mass does not surround or contain any of the canals or ducts, but appears to be merely an appendage, a gland, as it were, engrafted on the lower part. The canals and tubes are entirely confined to this part, as is also the case in the nephridia of Ocnerodrilus and Kerria.

The peritoneal sac consists of very large cells with small, sharply defined and very round nuclei. When these cells are empty they are very transparent and their walls are very plain. There are a few blood vessels on the peritoneal sac, and few of these cover also the folds.

Nephridia of Kerria (fig. 23). Having recollected *Kerria McDonaldi* in the pond near Miraflores in the Cape Region of Baja California, the only place where it is found to date, I have taken the opportunity to re-examine the nephridia in order to ascertain their resemblance to those of our present form as well as Ocnerodrilus. As a consequence I am able to correct some errors and to add several details. The general structure is the same as in the Ocnerodrilus and Phœnicodrilus and the windings of the canals the same as in the Argilophilus, etc. The two folds make a large rounded loop upwards, and join posteriorly in a very long spur partly free from peritoneal covering. The bridge connecting the junction of the spur and the posterior fold with the junction of the anterior fold, wide duct and narrow duct, is wide and ciliated, in fact it is the widest part of the canal. Posteriorly the canal of the bridge projects into the spur forming the widest of the four canals in this part. At the apex of the spur two and two of these canals are seen to join as usual, forming two loops, one outside of and above the other. The inner and lower one of these is the bend of the ciliated canal from the bridge, but it does not appear to be ciliated at this point.

The posterior fold contains as usual three canals, and so does the anterior fold. The rounded stretch where the two folds meet is more irregular in outline, and contains more windings than any other part of the fold, though not as many as in Pontodrilus. The nephrostome is connected with the main body by a slender and narrow tube, the connection being a little in front of the one between the wide duct and the main body. This wide duct is almost straight with only a slight curve away from the nephridium. It becomes slightly wider towards the nephropore, just before reaching which it turns sharply upon itself.

Another point of considerable interest is the presence of numerous blood capillaries on the nephridia, especially in the peritoneal sac, which they permiate. The blood has its origin from two vessels, one from the branch from the ventral main vessel and one from the branch from the dorsal main vessels, the two connecting by capillaries on the nephridial folds. Until now it has been supposed that Ocnerodrilus and Kerria did not possess blood vessels on their nephridia, but this is evidently an error as far at least as some species are concerned. Ordinarily these vessels are not visible and not distinct from the peritoneal cell-walls but a staining with orange G. will bring them out at once.

The *generative organs*, with one or two exceptions, resemble those in Ocnerodrilus in form and general arrangement, and if it were not for the regular absence of a prostate our species would be considered as a true Ocnerodrilus. The Spermatheca is very large and resembles in general outline that of *Ocnerodrilus Beddardi*. In species of Ocnerodrilus the spermatheca always stands up and is pressed close to the

anterior septum. In *Phœnicodrilus taste*, however, the spermatheca lies always flat pressed against the ventral side of the body-wall, and is of sufficiently large size to reach as far backwards as to the posterior septum between ix and x, which makes it about equal in length to the diverticula of the œsophagus (fig. 1, *spth.*) The lower part of the spermatheca is as usual more muscular than the free end, which in this species is more or less, though always shallowly, lobed, showing a large number of incipient diverticula irregularly formed and arranged. The spermatozoa are found principally in these warty diverticula.

Testes are very long and situated as usual in x and xi. The posterior one at least, and propably both pairs, connect with the sperm-sacs in the same somite.

Sperm-sacs are arranged as in some species of Ocnerodrilus. They are all paired. The anterior pair in ix is attached to the posterior septum of that somite. This pair is very much lobed, the lobes being more in number and in shape more round than in any species of Ocnerodrilus, the pair resembling two bunches of large grapes, completely filling the whole available space in the somite, especially above the diverticula and the œsophagus. The sperm-sacs in x and xi are less or hardly lobed, connecting with the the testes below, the latter, being long, slender and not branched, reach across the somite and joining the sperm-sacs in the posterior part near the septum. The sperm-sacs in xii are connected directly with those in xi, but otherwise attached to the anterior septum of somite xii. This pair of sperm-sacs are lobed but not as much so as those in ix.

There are two pair of ciliated rosettes in x and xi, and two pair of spermducts as usual leading from them. The spermducts join, as is generally the case, forming a single strand which runs close to, but a trifle more dorsally, than setæ 2, until somite xvii is reached. In this somite each spermduct enters a small muscular atrium devoid of prostate, and entirely confined to the longitudinal layer of the body-wall. As soon as entering the body-wall and this muscular chamber the two lumens of the spermduct, which until now had been separate, fuse together and enter the muscular chamber as one single duct.

As atrium I consider a small muscular chamber entirely confined to the body-wall, in which the spermducts open. This chamber is, however, devoid of any glandular cell prolongation such as we are accustomed to find in Ocnerodrilus, and ordinarily it ends where the spermducts enter, which is at the upper end of the layer of the body-wall. The atrium itself consists of an inner layer of epithelial cells, which at the very pore are much larger and furnished with larger nuclei, but which gradually decrease in size as they approach the place where the spermducts enter. This layer is a direct continuation of the hypodermal layer of the body-wall. An outside layer again consists of fine muscular fibres with smaller nuclei directly continued from the transverse muscular layer of the body-wall. We see thus that this short chamber might in reality be nothing but the remnants of a degenerated atrium, or rather remnants of the lower muscular part of a degenerated prostate, which glandular prolongation has disappeared. That this is the case I judge from the structure

found in one specimen differing from any other which I investigated. Out of six specimens which I sectioned off five agreed in all particulars as regards the absence of a prostrate, as generally understood in Ocnerodrilus, neither did seven specimens which I dissected show any trace of such a prostate. One specimen which I sectioned, however, showed an abnormal prolongation of the muscular chamber, in every particular resembling the lower muscular part or the atrium proper of the prostate as characteristic of Ocnerodrilus. It ascended inwardly in the cavity of the body as high as to setæ 3 and 4, ended here blindly without any differential glandular part or prostate proper, as is always found in Ocnerodrilus. Such "returns" to original characters and ancestors must, of course, be expected, and are the more interesting when encountered. We might on the other hand consider *Phœnicodrilus taste* as standing on a lower grade than Ocnerodrilus, the prostate not having yet appeared. But against such a view speaks the fact that her organs are as highly developed as in Ocnerodrilus, which would hardly be expected of a lower form, in which we would naturally look for a lower degree of development in several organs at the same time. A degeneration of a certain organ, however, such as the prostate, would not necessitate a similar degeneration of several other organs at the same time.

The absence of a prostate in Phœnicodrilus is of considerable interest, and I think it clearly demonstrates that the absence or presence of this organ cannot be laid at the foundation of families. Such absence of the prostate in an Ocnerodrilide is not unexpected. A perusal of the various species of Ocnerodrilus shows us how these species may be arranged in a series according to the size of the prostate, the list being headed by *Ocnerodrilus occidentalis*, with a very extended prostate, while at the other extremity we find *Ocnerodrilus Hendriei* with the most diminutive prostate, not extend ing outside of the somite. There is thus only a step further to Phœnicodrilus where this organ is entirely absent. That this fact will have some influence upon our views of the classification of Oligochæta is evident, and several genera or even families which hitherto have been considered far apart solely on account of the presence or absence of a glandular prostate, must now be brought closer together.

Ovary and *oviduct* occupy the same somites as in Ocnerodrilus and offer no characteristics of interest.

Habitat. I found this species in the Sierra el Taste, in the Cape region of Baja California, some 40 or 50 miles north of Cabo San Lucas, at an altitude of 4,000 feet. Later on I found specimens in great number in a garden at Pescadero on the Pacific coast, on the western slope of the same sierra, but at an altitude of only a few feet above the ocean. The water used for irrigation was taken from a creek coming from the sierra.

The species lives in damp soil and occur in great numbers, not mixed with any other form as far as my experience goes. The distribution of the species is most interesting as on the eastern side of the Sierra in the valley of San José, I never found any other Ocnerodrilid than *Ocnerodrilus Beddardi*. The question if the Sierra really absolutely divides the habitats of the two only forms of this family found in the Cape Region, further explorations are necessary to decide.

PONTODRILUS Grube.

The genus Pontodrilus, together with Photodrilus, is distinguished from all related genera by the absence of nephridia in the twelve anterior somites. In the majority of species the nephridia commence in somite xiii, but in two species they commence respectively in xiv and xv. A common character to all the species appears to be the very great thickening of the septa between somite v and xiii.

I have so far on the Pacific Coast only found one species of the genus Pontodrilus. Examinations were made from alcoholic specimens, I having no opportunity to examine them when I found them in their native habitat—Mexico.

Pontodrilus Michaelseni n. sp.

This species differs from all other species, except *P. Maronis*,* which have been referred to this genus in possessing a glandular crop occupying somites xiv, xv and xvi, as well as in other minor details. The habitat of the species is the very narrow moist line between high tide and dry soil on the shores of the Gulf of California around Guaymas, Mexico. The soil in which it occurs is very sandy and thoroughly soaked or moistened with the strongly saline water of the gulf. It occurred here in large numbers, but unfortunately at my visit most of the specimens were immature, only two possessing clitellum in the end of November, 1893. I dedicate this species to Dr. W. Michaelsen of Hamburg, whose labors in our common field are among the the most thorough and best.

EXTERIOR CHARACTERS.

The body of this species reaches a length of $3\frac{1}{4}$ inches with a width at the clitellum of less than $\frac{1}{8}$ of an inch, but the majority of specimens are somewhat smaller. The above measurement refers to specimens slowly killed and then hardened in alcohol. The body is tapering towards the tail end, the latter however being slightly swollen (fig. 24).

The prostomium encroaches on somite i, dividing it about one-half. Somite i is slightly larger than any of the following somites (fig. 25).

The clitellum commences in xiii and in full-grown specimens includes part of xix. It is incomplete in a peculiar manner. In xiii to xvii inclusive it is only developed on the dorsal side of the body. But in xviii and in part of xix the clitellum is only developed on the ventral side of the body, though this fact cannot be ascertained from exterior inspection. Viewed from the underside the clitellum appears to be on a line drawn through seta one. Between xvii and xviii the clitellar swelling recedes slightly, again to widen out in xviii, and here joining to a pair of ventral cushions, between which and the clitellum proper are situated the male pores.

Another pair of swellings are noticed around the spermathecal pores, covering on either side parts of somites vi, vii and viii (fig. 26).

* I received M. Perrier's memoir on Pontodrilus only after this paper was partly in print.

External pores. There are no dorsal pores. The spermathecal pores are found between somites vii/viii and viii/ix in front of seta 2, each one situated on a slightly elevated cushion. The ovipore in xiv in front of seta 1. The male pores are in xviii in front of and in line with seta 2 (fig. 26 ♂). The nephropores are in front of seta 2.

Setæ. The setæ commence in somite ii, eight in each segment and in couples. The distance between 3 and 4 is only slightly larger than that between 1 and 2. The distance between 1 and 1 is nearly twice as large as that between 1 and 2, and the distance between 2 and 3 is a little smaller than that between 1 and 1 (fig. 27).

Color of body pale flesh, rather transparent and marbled very much like Deltania. Clitellum yellowish.

INTERNAL ANATOMY.

Body-wall. The body-wall appears to me to be of unusual thinness, throughout the length of the body. The dorsal side is slightly thinner than the ventral side, at least anterior to the clitellum (fig. 29). Dorsally the longitudinal muscular layer is of about the same thickness as the transverse layer while on the ventral side the longitudinal muscular layer is about twice as thick as the tranverse muscular layer. This refers to the anterior somites. To this there is however an exception in somites viii and ix where on the ventral side in the vicinity of the spermathecal pores the transverse layer is thicker than the longitudinal layer. The transverse layer tapers down towards the spermathecal pores, but this thickening is found only in the immediate vicinity of the spermatheca. In the clitellar somites the relative development of the muscular layer is very different. Here the inner or longitudinal muscular layer is enormously thickened laterally in somites xvii and xviii or in the vicinity of the male pores (figs. 37, 38, 40, 41), while in the anterior part of the clitellum the longitudinal layer is only thickened ventrally, between the inner couples of setæ it here being at least twice as wide as it is dorsally (fig. 39).

Clitellum offers many points of interest. It has already been stated that this organ is incomplete, that is, not simultaneously developed on the dorsal and ventral sides. A section through an immature specimen shows (fig. 38) that the clitellar glandular layer is developed only between the seta, that is, from seta 4 ventrally to seta 4, while dorsally there is no trace of such cells. As regards the nature of these cells it is to be remarked that they are unusually small or rather thin compared to the larger and thicker cells of the dorsal part of the clitellum in the anterior somites of that organ. These latter cells offer nothing in particular of interest, resembling those of other genera of the family as far as I can make out. Unfortunately most of the specimens were immature and only two possessed clitellum, but these two had unavoidably not been treated, and had contracted to such very great extent that the finer structure of the clitellum had been hopelessly lost. From cross and longitudinal sections made it was, however, evident that the clitellar glandular cells, which constitute the clitellum, do not extend ventrally further than to setæ 1, thus leaving the ventral space

between setæ 1 and 1 with the usual layers less the glandular cells (fig. 41, *b. cl.*) marking the points where the clitellum ceases. We have thus before us a species with a dorsal and lateral clitellum in some somites, and with a ventral and lateral in one somite.

In all of the clitellar somites the inner or longitudinal muscular layer possesses an enormous development laterally, especially so in the region of the prostate, where it reaches a width four times that at the dorsal and ventral part. The reason of this enormous thickening of this layer is readily understood when we view one of the sections of this region. The part of the body-wall, on which rests the prostate, is attached by numerous arciform muscular bundles, arranged in a fan-shaped manner, to the dorsal and lateral sides of the body. These muscles are more numerous and stronger than any I have seen described in other species, making it possible for this region of the body to contract in a most characteristic manner.

When the body is opened and flattened out these muscles are seen to spread out from the male pore laterally, connecting the center of somite xviii with the two nearest somites xvii and xix as I have endeavored to show in fig. 42. As may be judged from the figure the muscles are arranged in regular fascicles of which we may count twenty-two to twenty-four as being more prominent and overlapping the other—a smaller number of fascicles situated below. The wider periphery of the attachment is situated on the body-wall above the prostate, but the lower and narrower part of the attachment of the fan is situated on a peculiar swelling which I have designated as the copulatory cushion (fig. 42, *c. c.*; fig. 41, *c. c.*; fig. 38, *c. c.*; figs. 44, 45), apparently a thickening of the longitudinal muscular layer, transversed by innumerable other muscles in every direction, all connected by what looks like connective tissue. The size of this copulatory cushion is very great; not only do these swellings project considerably outward but inwardly they encroach to a great extent on the internal cavity, especially so in mature specimens. This peculiar organ is entirely muscular, there being no sign of any outwardly opening papillæ. The prostate pore is situated between this cushion and the projection caused by the increased thickness of the longitudinal layer and the contraction of the fan-shaped muscles. In fig. 43 the section, a longitudinal one, is somewhat oblique, having followed the large muscular strands which surround the outlet duct of the prostate as well as the muscles of the copulatory cushion. Fig. 44 represents a more vertical, longitudinal section, more interior to the large fan-muscles, which do not show in the section except their inner attachments (*a. m.*) The large arciform strands vary considerably in size, those nearest the body-wall being the smallest, those nearest the intestine the largest. When a cross-section through somite xviii is viewed it will be seen that the smaller strands are filled between with connective tissue (fig. 41, *c. t.*), while a concentric transverse muscular strand is crossing them near the inner angle of the prostate pore. Other muscles connect the glandular prostate with the body-wall (figs. 37, 40 *m* and 42 *sp. m.*) The large strand *sp. m* in fig. 42, connects the bend of the prostate, where enters the sperm duct, with the ventral part of the body-wall under the ventral nerve-cord.

Septa. The first very pronounced septum is found between somites iv and v. Beddard has already remarked that the septa in *Pontodrilus hesperidum* are unusually thickened, some of them being thicker even than the body-wall at the point where they are attached to it. The septa in our present form are almost gradually increasing in thickness towards the one between xi and xii, which septum is the thickest, being almost as thick as the ventral body-wall. The septum dividing xii and xiii, while thickened, is much thinner, and those bounding the somites down to xix are almost normal in thickness, that is, equal those posterior to the clitellum. As a rule the attachments of the septa correspond with the intersegmental furrows. The septa bounding vii/viii and viii/ix are, however, exceptions as far as the place of their ventral attachment is concerned. These two septa are here affixed to the body-wall half-way between the setæ of the anterior somites, respectively vii and viii. This makes it appear as if the spermathecæ opened in the centre of the somite, when in reality they open as usual in the intersegmental groove.

Alimentary canal. The alimentary canal takes the shape of a long, narrow duct, singularly straight and without any prominent characteristics until it reaches somite xiv, in which somite commences a kind of gizzard of peculiar construction (fig. 29, *giz.*) Though this organ resembles a gizzard in outward form it is in reality no gizzard at all, but rather a glandular modification of the alimentary wall. With a gizzard we must of course mean an enlargement of the alimentary canal in which the muscular part has reached an enormous development in order to grind the food properly. In the organ referred to in our present species the muscular layers are on the contrary not increased in size, the thickening of the wall being caused exclusively by a new layer composed of glandular cells, which has been interposed between the transverse muscles and the inner epithelium, thus forming a glandular crop between the œsophagus and the tubular intestine. This organ occupies three somites, xiv, xv, xvi, or very much the same place as is so frequently the location for gizzard in other Oligochætæ. If we view a longitudinal section of the body through this crop (fig. 47) we find it to be more or less tapering towards either end. The large longitudinal blood vessel lies almost immediately on the top of the outer or chloragogic cells, in places penetrating them with connecting vessels which supply the underlining sinus with blood (fig. 47, *d. v. c.*).

The chloragogic layer of cells vary considerably in size. Sometimes there is more than one row of cells, one projecting above the other. The nuclei are oval and situated at the place where the cells become narrower. The longitudinal muscular layer is narrow, about two strands thick, immediately superposed the transverse layer, which consists only of one single thickness of strands (fig. 48 to 54 *t. m.*) The case generally observed in gizzards is that this layer is composed of a great number of strands more or less regularly arranged around a central plate. Below this transverse layer, commences the very thick layer of glandular cells, about 12 cells wide in centre. In the upper part of this layer are seen numerous blood lacunes, which in places join the muscular layers (fig. 49 to 53 *bl.*), at other times are more or less

perfectly enclosed in the glandular layer, forming generally a row of vascular lacunes near its outer margins (fig. 48 *bl. s.*) apparently without touching the muscular layer, or doing this only at certain places. Figs. 49 to 53 represent cross-section from different parts of the crop, from the posterior part, near the boundary of somite xvii (fig. 49), to the anterior part of xiv (fig. 52), illustrating the variations in thickness of the glandular layer. In the posterior part this layer is very thin (fig. 49 *gl.*) consisting only of a few cells, from one to three cells wide. In figs. 50 to 52 the glandular layer is seen to have increased in thickness and so has the inner epithelial cells. Fig. 53 is a portion of the glandular layer, in which the inner lumen is more plainly represented. The outer part of this glandular layer is divided up in lobes by the numerous blood sinuses, and in each such lobe there is a wider or narrower, generally, branched lumen, which, however, I have not been able to follow down to the epithelial cells.

The sacculated intestine commences at the posterior end of the crop, and offers nothing of great interest or characteristic.

There is no thyphlosole, but the intestine is otherwise very rich in blood lacunes.

Pharyngeal or *Salivary Gland.* Pharynx which occupies somites ii and iii is only developed dorsally. It is superposed by a large mass of glands and muscles, as is usual in a large number of Oligochætæ. In outline this glandular mass is remarkably even, especially so at its posterior end. In a longitudinal section we see customarily three lobes (fig. 29), supported by long strands of muscles, running back to the posterior boundaries of somites vi, vii and viii.

On the ventral side there are seen three of those muscular strands, similarly running back to vi, vii and viii, indicating that there is a row of similar strands corresponding with somites ii, iii and iv. In somite v there is a pair of smaller glands of similar nature attached to muscles which connect with the larger strands of the main gland (fig. 29, *s.s. gl.*)

A cross-section of this glandular mass (fig. 30), shows us that the glands are situated principally on the periphery, supported by muscles (*ms.*), while the inner and posterior part is principally taken up by strands and ducts. A division of the mass in three more or less distinct layers is discernible, probably corresponding to somites ii, iii and iv. These glands communicate directly by means of ducts with the epithelium of the pharynx. In fig. 29 these ducts are roughly represented as dark violet. In the cross-section (fig. 30), the darkest blotches are intended to represent the ducts, while the lighter colored violet ones are the glands. In fig. 31 a lobe of the longitudinal section is seen in a larger magnification, and in fig. 32 a smaller lobe, yet more highly magnified. The glandular cells are rather of varying size, and arranged around the margin of glandular sack, leaving the inner space open. The cell cytoplasm is massed in places, leaving in other places larger or smaller, generally roundish, vacuoles (fig. 35, *va.*)

In figs. 33 and 34 I have endeavored to show the relative arrangement of the muscular strands, the glandular ducts and the glandular cells. As will be seen these

ducts are in places entirely closed in by muscles, while the glands themselves are only supported by them.

The ducts lead directly to the pharyngeal epithelium; arrived here they branch out sending numerous discharge-tubes between the epithelial cells (fig. 36 *gl. dt.*), discharging the salivary mucous in the pharyngeal cavity. These ductules are frequently, though not generally, branched while in the epithelial layer. Each ductule is furnished at the distal end with a small storage chamber (36A) of oblong form and considerably smaller than the nucleus of the epithelial cells.

Septal glands. As has already been stated there are five pair of very small glands, which are pricipally attached to the connecting vessels in somites v to ix, and situated on the ventral side of the œsophagus. These glands do not hang on closely to the septum, but are apparently suspended from it only by a few tiny mesenteric tissues and by a muscle or two. In longitudinal section they appear as suspend entirely between the two septa (fig. 29), while in cross-section they are seen to be affixed to the connecting vessels and from them project laterally, the point of affixion being close to the ventral vessels (fig. 70 *gl.*) The general outline of these glands resemble the so-called liver cells attached to the connecting and other vessels in some Lumbricides, but the structure is similar to the salivary glands. The gland in v resembles exactly the structure in the salivary glands which open in the pharynx, it being transversed by blood capillaries, infested with the same parasites, supported by muscles, and finally is only sparcely surrounded by floating, globular, cœlomic cells. The other gland in vi to ix are all surrounded by a thick coating of these floating cœlomic cells. These glands stain in the same way as the salivary glands, their secretions being stained deep violet with hæmatoxylon-orange, while the cœlomic cells stain pale yellow. A fine and very thin duct runs backwards and upwards from the far upper end of each gland towards the alimentary canal to its junction with the septum, but I have some doubt about it emptying into the intestine, and it is much more probable that in Pontodrilus, as well as in Phœnicodrilus and Ocnerodrilus, these septal glands empty into the pharynx. None of my sections, however, show this to be the case. Certain it is that in Pontodrilus the various septal glands are not as closely connected with the salivary glands as in the just mentioned genera, in which the respective glands are actually not only suspended from the same longitudinal muscular band, but along and resting on the latter run also the collective ducts of the glands. Among the salivary and septal glands are seen numerous irregular, generally oval or oblong bodies full of nuclei. These are the terminal pockets of the capilaries, generally termed blood glands.

Blood glands (fig. 73A, *t.*). Ed. Perrier was the first to describe blood glands in Pontodrilus, but he found them exclusively in the blood vessels or at the end of the capilaries investing the nephridia. In our present species, *P. Michaelseni*, I have found these glands only in the capillaries of the salivary and septal glands. They here occur in very large numbers, especially in the former, being massed at or near the posterior edge of the gland in varying numbers. Some specimens con-

tain comparatively few blood glands, others three or four times as many. They are of all sizes and shapes, as Perrier has shown. Some contain only one single nucleus, then frequently surrounded by a blood clot; others again contain a very great number of nuclei, which are then situated in a sac-like pocket at the end of the blood capillary. In some of the larger blood vessels in the salivary gland the blood gland takes the form of a "hertzkörper." The smaller ones situated on the capillaries may be named terminal blood glands, while those situated inside the larger vessels may be designated interior blood glands. The structure of the two are at least in this species very similar.

In fig. 73, *a.* to *s.*, I have endeavored to illustrate the structure of these blood glands from sections. In *g.* a large blood vessel with a blood clot, at the base of which is an inner blood gland. On one side of the blood vessel is a part of a salivary gland with brown secretions. In *a.* a small terminal blood gland is shown, and in *b.* and *e.* some of a greater development. The nuclei are not always surrounded by a distinct cell membrane, in fact in almost every gland are found some nuclei with distinct cell membranes while others lie loose in the granular serum. The exterior line in all the figures represents the wall of the blood vessel, and the difference between the terminal and inner blood glands consist in reality only in the absence or presence of blood surrounding the glands. As far as the granular protoplasm concerns it is always differentiated in two parts. The one at the distal extremity is more evenly diffused and finer grained than the one next the capillary, which again is coarser, streaky and which, besides, stains differently or at least more intensely than the other. Many of the glands contain larger or smaller bodies (*p.*, *t.* and *o.*) equally of round form and lighter in color than the cytoplasm, but sometimes they are very opaque, staining deeply as at *r.*, the two classes probably being of entirely different character. The former resembles a pale nucleus, while the latter opaque bodies appear only to be secreted matter. The paler ones may possibly be parasitic protozoa.

The blood glands described by Claparede, Lankester and others in Lumbricus, etc., are probably of a similar construction, and judging from the figure given by Michaelsen of the "hertzkörper" in Enchytræus, we may conclude that it, too, is identical with the blood gland in Pontodrilus.

Spermathecæ (figs. 30, 55, 56, 57, 58). There are two pair of spermathecæ found in somites viii and ix, the exterior pores being as usual in the intersegmental grooves between vii/viii and viii/ix in line with setæ 2. Each spermatheca possesses a tubular diverticulum, the junction of the two being in the body-wall. The position of the diverticulum is always ventral to the spermathecæ proper. This is cylindrical, quite narrow, with a larger globular chamber at the free inner end, in which the wall is much thinner than in the cylindrical part. At the junction with the body-wall is a much larger swelling, the lower and more strongly muscular part of the main cylinder being greatly widened, presenting a muscular cushion partly projecting above the body-wall, partly again being immerged in it. The spermatozoa are principally massed in the inner globular chamber, though they are seen also in the diverticulum.

The main spermatheca is strongly muscular, especially at its lower end where the muscular layer is much thicker than the inner epithelial cells. These latter are large with oval nuclei. Outside of these cells and between them and the muscular layer are seen a row of interstitial nuclei of much smaller size than the nuclei of the epithelial cells (fig. 56 *intes. n.*) The structure of the diverticulum is somewhat different. Interiorly we find large epithelial cells with large round nuclei. Outside of them is a single row of interstitial nuclei. Surrounding them we find a circular muscular layer varying in thickness (fig. 57, *c. m.*) and with few, small nuclei. Exterior to this layer are seen numerous blood vessels, and outside of them a two or three cells thick layer of glandular cells (*gl. c.*)

When the body of the worm is viewed from the interior, with the alimentary canal removed, the spermatheca as well as their diverticula are seen to extend backward, parallel with the ventral ganglion. The diverticulum is always much shorter and narrower than the spermatheca proper.

Testes and *Ovaries.* The former organs consist of two pair of minute narrow-lobed bodies (fig. 29, *t.* 59, 60), the lobes being all in one plane, parallel to the body-wall. One pair are in x and one in xi as usual.

The ovaries consist of one pair of flat bodies with wavy margin and wide and shallow lobes, distributed in both a horizontal and vertical plane (figs. 61 and 62). As usual the ovaries are in xiii.

The *oviduct* is placed as usual with the funnel in xiii and the pore in xiv. The funnel part is very thick, fig. 63 drawn from a longitudinal section.

Ciliated rosettes, Spermducts and *Prostates.* There are as usual two pair of ciliated rosettes in x and xi opposite the testes. The funnels are very thick and not much crimpled or hardly crimpled with one flare on either side. The epithelial nuclei are quite long, and their cells are superposed a thick layer of very distinct blood vessels (fig. 65, *cr.* 66 and 67). The spermducts unite to a single duct which passes immediately outside of the second setæ. The duct is unusually narrow, the narrowest I have seen in any species of this size. The spermduct enters the glandular part of the prostate just above the intersegmental groove separating xviii/xvii (fig. 42, *spd.;* 68, *spd.*)

The prostate is tubular, very large, bent upon itself once. It starts from the male pore, which is situated in the center of xviii, forwards, running parallel with ventral nerve cord. When it reaches xvii it turns backward, its apex being in the center of xviii. The prostate consists as usual of two distinct parts, connected in the center of xvii. The advancing part is strongly muscular, the returning part again is glandular. The prostate is cylindrical, the two halves being almost equal in thickness. The part which penetrates the muscular body-wall is several times thinner than the other part. The muscular part consists of two layers, the inner one consisting of a row of epithelial cells with oblong nuclei. The outer layer, which is very thick, consists entirely of circular muscles with a few small nuclei.

The glandular part of the prostate which commences at the anterior bend of the organ consists of two or possibly of three layers. The inner lining consists of only one layer of epithelial cells with ovoid nuclei. These long cells appear to be surrounded by a narrow zone of fibrous or perhaps muscular tissue with few nuclei. But by far the greatest part of the prostate consists of fibrous tissue with numerous small roundish nuclei, with here and there a cell being visible, and with a few cells of a glandular appearance (fig. 68), especially toward the circumference. In cross-section the anterior part of this prostate is triangular in outline, while the muscular part is always circular, and in size always thicker. The very narrow part of the prostate which penetrates the body-wall is strongly muscular of the same general structure as the free muscular part. The general structure of the prostate appears similar to the one of *Pontodrilus hesperidum* as described by Beddard. He has pointed out the absence of a regular layer of glandular cells in the prostate of that species, and it is possible that this construction of this organ which thus approaches that of Ocnerodrilidæ, is not a species but a generic character, if it does not prove to be of even greater value.

Vascular system. There are a dorsal and ventral vessel, but no subneural, nor any subintestinal vessel, and no thyphlosole. The two main vessels are connected with hearts in x, xi, xii, xiii, the most posterior one of which is found in somite xiii, immediately in front of the sacculated intestine. This heart is the largest, the others gradually decrease in size forward. The posterior part of these vessels are entirely free of brown cells. The ventral vessel is forked in somite ix in two parallel lateral vessels, there being no central vessel left. These two branches are always of unequal size, both being situated immediately under the œsophagus (fig. 64 *v. v.*) In the somites anterior to x, these branches of the ventral are connected by laterals with the dorsal vessel. In one specimen the ventral fork commenced in xii (fig. 64).

Between the dorsal vessel and the ventral forks there are connecting vessels, one pair in each of the somites v, vi, vii, viii and ix. To the ventral parts of these connecting vessels are attached oblong glands, which again are surrounded by a coating of globular brown cells. These glands do not extend clear to the dorsal vessel, but end laterally before reaching it. The nature of the glandular cells appear the same as those of the pharynx, staining in exactly the same way. The cells of these septal glands are more numerous in the anterior somites, gradually diminishing posteriorly, while the opposite is the case with the free round cells which are more numerous in the posterior glands (figs. 29 *gl.* and 71 *gl.*)

Nephridia (figs. 71 and 72). These organs commence in somite xiii, or in the same somite as the ovaries. The first two anterior nephridia are furnished with a smaller covering of peritoneal cells, but already in xvi do the nephridia attain their full size, as in all posterior somites.

The nephridia are built upon the same general principles as those of Argilophilus, Deltania, Ocnerodrilus and Phœnicodrilus, as well as of Lumbricus as shown by Benham. We find here the corresponding ducts, canals, lobes, etc., and a gen-

eral description of them will be superfluous. The spur is directed backwards and the two folds are directed upwards in about right angle to the spur and narrow duct as well. The spur and the folds rest on the large lobes of peritoneal cells, one of which is posterior and one anterior. The posterior one surrounds the spur, upon the anterior one, which is the smallest, rests the two folds. The narrow duct is not unusually narrow, while the wide duct or outlet duct is very narrow, not any wider than the narrow duct. The neck of the anterior fold is, where it connects with the narrow duct, very wide, enlarged, irregular and sigmoid, gradually increasing in size to the anterior fold. Where the two folds join, the fold is always very coiled. The tube forming the bridge is not any wider than the clear canals, but it is less clear or transparent, just as in Lumbricus. The canal leading from this bridge into the anterior fold, is straighter, darker, and slightly wider than the two bright tubes which are much coiled and situated more anteriorly and superiorly to the straighter canal. This coiling ceases as soon as the big bend and windings are passed and the posterior fold is reached.

The nephrostome is large. The marginal cells in the rosette are only slightly decreasing in size toward the extremities or centripetal marginals. There is a large centripetal protuberance surrounding the inner opening of the duct, as in Lumbricus. as described by Benham, but the centrifugal cells are less regular and more scattered, The centrifugal cells are never hidden by the centripetals as in Lumbricus, and the whole centripetal protuberance is most prominent seen in whatever direction. The outlet duct enters the fold much closer to the narrow or nephrostomal duct than is usual in Oligochæta, in fact it connects with the free neck of the anterior fold, close behind the septum.

The relationship of *Pontodrilus Michaelseni* to the other species of the genus is not as clear as we might wish. Beddard's description and notes in his paper, "V. Some new or little known Oligochæta," are the only comparative remarks yet made on the few worms which are grouped under this genus, an arrangement which must be considered as entirely preliminary. The only very characteristic features which connect the six species of the genus is the commencement of the nephridia posterior to somite xii, and the opening of the spermduct into the prostate, absence of typhlosole, grape-like sperm-sacs, and no penial setæ. None of these species have been sufficiently described, an unavoidable fault attendant all species immersed in alcohol without previous careful preparation and evacuation. In the following table I have endeavored to compile the characters of the various species as far as I can make out from the descriptions, no specimens for comparison being in my possession. I include here, as suggested by Beddard, the genus *Photodrilus* Giard. I have had no access to Grube's description of *P. littoralis*, and have therefore excluded it from this table.

SPECIES OF PONTODRILUS AND PHOTODRILUS.

	P. Michaelseni n. sp.	*P. arenæ* Fr. Müller & Michaelsen.	*P. hesperidum* Bedd.	*P. insularis* Rosa.	*P. Marionis* Perrier.	*P. phosphoreus* Dugès.
Nephridia commence in somite	xiii.	xiii.	xiii ?	xiii.	xv.	xiv
Nephropores in line with seta	2.	?	?	4.	2.	2.
Gizzard	Rudimentary.	Absent.	Absent.	Rudimentary.	Rudimentary?	Absent.
Œsophageal swellings	None.	None.	None.	None.	None.	Four in x-xiii.
Glandular crop	Large in xiv, xv, xvi.	None.	None.	None.	Present.	None.
Septal glands	In v to ix.	?	None.	None.	Present.	In v-ix.
Penial setæ	Absent.	Absent ?	Absent.	Absent.	Absent.	In xviii and xii
Common setæ	Plain, regular.	Ornamented, regular.	Plain, regular.	Plain, irregular behind.	Plain, regular.	Plain, regular.
Spermatheca	Two pair in viii and ix; one diverticle.	Two pair in viii and ix; one diverticle.	Two pair in viii and ix; one diverticle.	Two pair in viii and ix; no diverticle.	Two pair in viii and ix; one diverticle.	One pair in ix; one diverticle.
Sperm-sacs	Two pair, grape-like, in xi and xii.	Two pair, grape-like, in xi and xii.	Two pair, racemose, in xi and xii.	Two pair, grape-like, in xi and xii.	Two pair in xi and xii.	Two pair in xi and xii.
Clitellum	xiii–xviii, incomplete.	xiii–xvii, incomplete.	?	?	xiii to xvii complete (?).	xiii–xvii ?
Prostomium	Encroaches on somite 1.	Encroaches ½ on somite 1.	?	Does not encroach on somite 1.	Encroaches on somite 1.	Does not encroach on somite 1.
Ventral papillæ		In xvii and xix			One central, xix–xx, and one ditto, xx–xi.	
Habitat	Guaymas, Mexico.	Desterro, Brasil.	Jamaica.	Aru Island.	Marseilles.	France.

In the above table I have principally followed Beddard, but I cannot agree with his opinion as regards the identity of Grube's *P. littoralis*, with that of *P. Marionis* of Perrier. As Perrier remarks, the ventral median papillæ described by him in *P. Marionis* are not found in *P. littoralis*, in which species these papillæ were paired. Until Grube's species has been found and redescribed we must therefore accept it as a separate one. It is of course not by any means impossible that one or more species of Pontodrilus are to be found in the same locality.

In reference to the gizzard I have given it as rudimentary in two species. This refers only to an anterior gizzard close behind the pharynx, in which the muscular layer of the œsophagus is simply thickened as shown in fig. 46 A and B. Beddard says that *P. littoralis* Grube has also a rudimentary gizzard, but I think that he judges by M. Perrier's description of what I call a glandular crop in the somites posterior to the testes. It may not be impossible that the muscular thickening of the œsophagus really exists in all the species more or less prominently, as it is easily overlooked.

That the glandular crop really exists in *P. Marionis* is evident from Perrier's drawing (fig. 22, pl. xvi), though I cannot accept the epithelial nature of the cells. Perrier says nothing of the place from which this drawing is taken, but I suspect that it was from a section of the intestine between the tubular and sacculated parts, similar as in *P. Michaelseni*.

LITERATURE.

Beddard, Fr. E. Abstract on Some Investigations into the Structure of the Oligochæta. Ann. Mag. Nat. Hist. Jan., 1891, p. 96.

Beddard, Fr. E. Some New or Little Known Oligochæta. Proceedings of the Royal Physical Society, Edinburgh, June 13, 1893.

Beddard, Fr. E. On the Anatomy of Ocnerodrilus. Proc. Royal Society of Edinburgh, vol. xxxvi, p. 563.

Michaelsen, W. Terricolen der Berliner Zoologischen Sammlung II, page 14.

Benham, W. B. An Attempt to Classify Earthworms. Quarterly Journal of Microscopical Science, vol. xxxi, part ii, page 243, etc.

Rosa, Daniele. Sui Generi Pontodrilus, Microscolex, e Photodrilus. Boll. Mus. Torino, vol. iii.

Rosa, Daniele. Die Exotischen Terricolen des K. K. Naturhist. Wien. Annal. K. K. Nat. Hofmus. Wien, Bd. vi, p. 387.

Eisen, G. Anatomical Studies on New Species of Ocnerodrilus. Proc. Cal. Acad. Sci., ser. 2, vol. iii.

Eisen, G. Anatomical Structure of Two Species of Kerria. Proc. Cal. Acad. Sci., ser. 2, vol. iii.

Perrier, Edmond. Etudes sur l'Organisation des Lombriciens Terrestres. IV Pontodrilus. Archives Zoologie Experimental, vol. ix, pages 175 to 248, pl. xiv. to xviii.

Eclipidrilus frigidus Eisen.

Through the kindness of a friend traveling in Sierra Nevada I have received a small number of specimens of this interesting oligochæta, but unfortunately all the specimens were in a poor state of preservation and much macerated. However I was enabled to make several very nearly continuous series of sections and thus settle several very important points in the anatomy of this worm. My former study of the species was entirely dependent on dissection, which could not possibly reveal all the details of this minute species, especially as regards the spermducts, the presence of which I am now able to demonstrate. My present researches show that the species is less erratic in its anatomy than I first supposed, while again in many respects it differs strangely from its nearest allies, the various genera of Lumbriculidæ. For the present I retain the family of Eclipidrilidæ, but not on the same grounds as formerly, and I now consider it rather as a subfamily to Lumbriculidæ than one standing isolated, however with strong leaning towards Moniligaster.

The generative organs are situated as follows:

Testes, two pair. The anterior pair attached to the anterior septum of somite ix. The posterior pair similarly to the anterior septum in somite x.

Ovary, one pair attached to the anterior septum of somite xi.

Oviduct in xii, opening in front of the inner pair of setæ.

Spermathecæ, one pair in ix opening posterior to the setæ and near the posterior septum.

Atrium and *prostate*, one pair opening in x, posterior to the inner pair of setæ. This organ, which is very long, occupying seven to eight somites, consists of three parts, first, one anterior atrium and prostate proper, second, a thin and narrow part

connecting the former with, third, the posterior one, a storage chamber for spermatozoa.

Spermducts are two pairs, exceedingly narrow, opening close together in the posterior part of the storage chamber.

Ciliated rosettes, two pairs, the anterior pair opening in ix. The posterior pair in x, both in front of the septum. They are exceedingly thin and flat. The posterior wall is attached to the septum.

Sperm-sacs consist of a pair of very long continuous sacs, which cover the generative organs, including the spermatheca, and extending from somites x to xvii or xviii, generally several somites posterior to the caudal part of the storage chamber.

Setæ are 8 in 4 pairs in each somite, commencing with the second.

The *vascular system* is characterized by blind forked vessels in the posterior 30 odd somites, thus bringing the genus in close relationship with Lumbriculidæ. Another characteristic is the two loops of lateral vessels which branch out from the main vascular trunks in somites ix and x, and which run backwards as far as the end of the storage chamber. The anterior eight somites contain winding lateral vessels connecting the two main dorsal and ventral trunks. Hertzkörper in the dorsal vessel as well as in the branches in the intestine. After these preliminary references to the main anatomical points I will enter more fully upon the anatomical and histological structure of the various organs.

Body-wall and Clitellum. The finer structure must be left for future study. The inner longitudinal muscular layer is considerably thicker than the transverse layer and hypodermis together. The longitudinal strands are very thin and ribbon-like, some being much longer than others and reaching through the width of the layer, others being very much smaller, situated principally close to the transverse layer. Figs. 77, 79, 99, etc.

The clitellum comprises about 6 somites, commencing in the posterior part of ix and extending to the center or posterior part of xiv. The clitellar glandular cells, one layer thick, are oblong, irregular, flask-like, containing very coarse, angular, grains (fig. 79). They are separated or interspersed by large non-staining cells. The peritoneum is rather poor in blood vessels, but the layer is very thick, in places almost as thick as the longitudinal muscular layer (fig. 82, *pr*).

Septa. None of the septa are abnormally thickened. The first distinct septum is seen between somites v and vi. The septa are straight, not cup-shaped. Those surrounding the various divisions of the prostate are much firmer than the others. They constrict the prostate, in fact the latter appears notched at every septum (figs. 78, 92, 94).

Alimentary canal. The alimentary canal can properly be only divided in two parts—pharynx and intestine. The pharynx which ends in somite v is developed latterally and dorsally, but not ventrally (figs. 83, 77). The thickened part is very thick, consisting of the usual narrow and almost filiform cells. The ventral part is

very thin, thinner in fact than any other part of the alimentary canal. Of the balance of this canal there is no distinction between œsophagus and sacculated intestine. The gut is every where sacculated, only increasing in thickness towards the genital somites, where it is thickest. The alimentary canal throughout its length is lined by a columnar, ciliated epithelium, outside of which is a very thick vascular layer, with large blood lacunes, directly connected with the dorsal and ventral vessels, which are closely attached to, or almost imbedded in the intestine. The latter as well as the vessels are covered with chloragogic cells, which, especially in the region of the dorsal vessel, are very large (figs. 85 to 91), the layer being thickest close to the strands of mesenteric tissue connecting the intestine with body-wall.

The free cœlomic lateral vessels in the eight anterior somites are similarly surrounded by a thick mass of glandular cells, arranged around muscular strands, and which are quite distinct from the chloragogic cells and more resemble real glands. Their reaction to stains is entirely distinct from that of the chloragogic cells of the main vessels and of the alimentary canal, staining very deeply with ammoniated hæmatoxylon (fig. 84), and showing a coarser grainy secretion, while the real chloragogic cells remain much more pellucid and contain much finer grains. Cells similar to the former are also seen attached to the cœlomic covering of the prostate (fig. 107, etc.) They also greatly resemble the glandular cells, or multicellular glands from the pharynx of Pontodrilus and other oligochæta, possessing pharyngeal glands.

The vascular layer of the intestine is very much developed, especially on the ventral side, where it connects with the ventral vessel, through a thick band of mesenteric and connective tissue. This as well as the walls of the blood vessels were so thickly studded with a protozoa (Hæmagregarina) that the structure of the layer could not even in a single instance be properly made out.

There are no pharyngeal glands, though a few glandular cells are seen scattered about between the muscular strands connnecting the pharynx with the body-wall. But these cells resemble more chloragogen cells than true pharyngeal glands.

The *testes* are of no unusual structure. The anterior pair, in the specimens I opened, are smaller than the posterior pair, which were always forked, while the anterior pair was undivided.

The *ovary* in xi is always sigmoid of irregular shape and present the peculiarity that seldom more than one ovum is developed at a time, this one being situated not at the periphery or at the free end of the ovary, but in the inner angle of the sinus. The ovum is unusually small in size and readily detached from the gonad (figs. 78, 108). It grows large after separation, and is found in numbers in the posterior somites.

The *ovary* is of large size reaching far back to the posterior septum. Its lower end is not only attached to the septum and body-wall, but also to the narrow end of the outer sperm funnel (or ciliated rosette) fig. 96. In one of the specimens sectioned the ovaries either extended past the oviduct through somite xii, or there was a second pair of ovaries in xii. Beddard has similarly remarked that the ovary in Sutroa is attached to the cells of the spermiducal funnel.

Spermatheca. As stated there is one pair situated in ix, the spermathecal pore being posterior to the setæ, and in line with the inner couples. The spermatheca consists of two distinct parts, as is usual in this group, the lower muscular part, and an upper rounded part consisting of an unicellular layer of dice-shaped cells. This rounded chamber was sometimes situated in the same somite, ix, as the muscular body, but frequently it projected backwards into somite x.

The structure of this muscular part is represented in figure 82. The inner epithelial layer, consists of narrow columnar cells, with rounded nuclei and striated protoplasm. Exterior to this layer, there is a thin one of transverse or circular muscles, outside of which again is an epithelial stratum one or two cells deep, with slightly oblong nuclei, the cells themselves being irregularly dice-shaped (fig. 82).

Prostate and spermducts. The most interesting, as well as the most complicated structure of this species, is the prostate, of which I am now able to give a fuller account, which I believe will not leave any of the points of its structure in doubt.

I have already referred to the three main divisions of the organ, the proximal one consisting of a long cylindrical tube, containing penis, atrium and prostate. Second, a very narrow tube of almost the same structure as the prostate part of the former, connecting with a long cylindrical chamber of somewhat modified structure, into which the two spermducts open, quite near its junction with the narrow part or bridge. If we, however, disregard the difference in size of these various parts and only consider the structure, we find that the whole organ may also be divided in three parts:

First, the proximal part, which is entirely confined to somite x. This part is upright, so to say, does not run backwards; it is also somewhat bent, forming a right angle with the balance of the organ. This part consists of penis, and a long tubular part which, in want of a better name, I designate as atrium (fig. 100 *atr.* and *p.*). With somite xi commences a change of structure of this organ, common both to the wide part and to the very narrow posterior part. I will refer to it as the prostate proper, as it contains the thick layer of regular prostate cells so common in all higher oligochæta where this organ occurs; it is the "two layer"—prostate of Beddard. The third part or storage chamber is characterized by the absence of this layer.

I will now refer to each one of these three or four parts in succession and more in detail, beginning with the penis and atrium.

Next to the body-wall, ending at the transverse muscular layer and from there stretching inwards, is a reversible sac—a preputium—consisting of epithelial cells, with very large, round, compressed nuclei and striated contents. This epithelium is surrounded by a thin muscular layer (fig. 100, *pre.*, 101).

Into this preputium opens a penial glans (fig. 100 *p. gls.*, 101, etc.), consisting of two separate covers, posteriorly attached to a collar of larger rounded or pear-shaped cells, at the base of which are seen a number of muscular plates. This collar is folded on itself, one part of the fold connecting with outer and one part with the inner cover of the glans. Through the median line of these parts runs a long, very

narrow excretory tube with thick walls. Nearest the male pore this tube is quite straight, or only slightly folded, but at its distal end the windings are greatly packed or irregularly coiled (fig. 99, *tube*).

The part posterior to the penial collar I have designated the atrium proper, simply because it does not contain any inner layer of glandular cells, and because in its distal end it connects with the true prostate. The excretory tube continues all through this part and is, so to say, suspended in a more or less dense mass of fibrous tissue. Nearer the collar this mass is reduced to a few strands only, but towards the distal end it becomes quite dense, especially so nearest the tube, while towards the periphery it is much less dense (fig. 92, *f. t.*, fibrous tissue; *f. st.*, fibrous strands). Fig. 100 represents a cross-section taken near the distal end; the tube is seen coiled in the center, while fibrous tissue connects it with the walls of the atrium.

The exterior layers of the atrium are constructed very much as the same layers of the prostate proper and the storage chamber. There are three layers which are common to the two different parts of the prostate. Interiorly a thin layer of circular muscles somewhat variable in thickness in different parts, but generally only three or four strands thick. Exterior to this layer runs a spirally wound layer of longitudinal muscles, arranged in band-like plates, and when seen in cross-section resembling a row of fringes (figs. 100, 101, 102, 103, 106, 107, *l. m*). Fig. 107 shows these plates, highly magnified, to consist of rather rectangular muscular strands. Exterior to this layer of *l. m.* muscles we find everywhere a broken row of prostate glands of very minute size, appearing to penetrate in between the muscular plates, though on account of the macerated condition of the tissues I could not follow their tubes. These small glands, which barely project outside of the muscles, are found everywhere from the distal end of the storage chamber to the penial collar, wherever this muscular layer is found. In places they are continuous, in others scattered about, seldom more than one row thick (fig. 101, *gls*). But as we reach the region of the narrow part of the prostate and especially the part of the storage chamber where the spermducts enter, we find another thicker layer of prostate glands similarly scattered over the longitudinal muscular fringe (figs. 102, 103, 106, 107, *pr. gl. s*, small prostate glands; *pr. gl. l.*, large prostate glands). In the region where the spermducts enter the storage chamber this layer of large prostate cells is almost continuous and considerably thicker than the muscular layers combined (fig. 103).

The prostate proper contains besides these layers of muscles and exterior prostate glands two inner layers, which resemble and propably correspond to the two cell-layers found in the prostate of the higher oligochæta, viz.: one layer of lining epithelium (fig. 101) and one layer of glandular prostate cells, with very large nuclei, and separated one from the other by transparent spaces, through which possibly enter projections of the exterior prostate glands. These two characteristic layers do not extend to the narrowest part of the prostate. Hence the muscular layer is covered by a single row of inner lining epithelium with large, slightly oblong nuclei (fig. 102), which in the very narrowest part are about 12 to 14 in the row.

The proximal end of the storage chamber is lined by a very thick epithelium

with very oblong nuclei (fig. 105 *ep.*). This epithelium is thickened only at the anterior side, nearest the narrow tube (fig. 104), but narrows quickly both superiorly and posteriorly. The inner transverse muscular layer is similarly thickened in this region (fig. 105, *t. in.*).

The storage chamber contains the same general layers as the narrow bridge. The inner lining epithelium is narrow, with very compressed nuclei, with the flat side lying against the muscular wall (fig. 107).

The nature of the prostate differs apparently much from that of the prostates of some members of Lumbriculidæ, especially Sutroa, as lately more minutely described by Beddard, but more resembles in structure Lumbriculus. But I am more inclined to compare its makeup with the prostate of Moniligaster. In Eclipidrilus the prostate contains the characteristics of both Limicolæ and Tericolæ, if I may yet use the expression. The inner two-celled layer of the prostate which is characterizing most higher earth worms, possessing a prostate, is superposed by the layers, muscular and glandular which characterize Tubifex, Moniligaster, etc.

Spermducts. I am now able to describe the spermducts for the first time. They enter the storage chamber of the prostate near to the bridge and close together, but still entirely separate (fig. 95), and when the inner surface of the chamber is viewed from above the entrance pores are seen as two small slightly elevated papillæ (fig. 95 *sp.*) From these the spermducts, which are of very minute size, run forward parallel to the prostate, one on either side, except alongside of the bridge where they run close together. The outer pair leave the prostate in xi, dip down to the ovaries in which they are partially engaged and push their ciliated rosettes through septum x/xi, the rosettes opening in x. The inner spermducts are similarly engaged in the gonads in x, push through septum ix/x and open their rosettes in ix, all very close to the body-wall.

The rosettes are only one cell thick, very thin and flat, with the posterior surface attached to the septum, the anterior lip only being free. Only the inner deeper surface of the rosettes is ciliated.

Sperm-sacs, one on each side and continuous from the beginning of the spermatheca, reach as far back or further than the posterior end of the storage chamber of the prostate. Generally the sperm-sacs reach two or three somites further back. Each sac is separate from the other and consists of one continuous bag contracted somewhat at the septa. It is not racemose and does not connect with the septa as in so many of the higher forms, but greatly resembles those of Sutroa. The sperm-sac only covers the prostate, but does not properly enclose it, as it does not extend to the space between the prostate and the intestine. With the latter, however, it is connected by two continuous walls of connective tissue, one on the dorsal and one on the ventral side of the intestine. In the enclosure thus formed the prostate, as well as the upper part of the spermatheca, lies free.

In the posterior parts of the sperm-sacs are always seen very large sacs of yolk granules. In one specimen I found a mass of these yolk granules surrounding the

spermatozoa in the prostate storage chamber (figs. 120 to 123). The yolk sacs are frequently so large that they fill the larger part of the cœlomic cavity pressing the intestine close up against the wall of body.

Nephridia. The most anterior nephrostome is found in iii in front of septum iii/iv. The most anterior nephropore is found in iv in front of the inner couple of setæ. There are nephridia (pores) in iv, v, vi, vii and viii, while somites x, xi, xii have no nephridia. The neck of the nephrostome contains a large glandular swelling, to which is attached muscles connecting with the septum. This neck is perforated by several narrow ductules, which occasionally branch. The duct appears to consist of a single tube not covered by peritoneal glands. On account of the rather macerated condition of the specimens I could not investigate the nepridial structure any closer.

Some of the specimens collected by my friend were from a new locality and somewhat larger in size. This locality is Three Spring Meadow, on the east side of the North Fork of Kings River, opposite the natural bridge, at an altitude of about 8,000 or 9,000 feet, and several thousand feet above the river bottom at that point. They were there found under some old logs lying across the meadow, and over which the water was flowing, the worms being attached to the surface of the decayed wood. These specimens were about $\frac{1}{3}$ larger than those from the springs at Alpine Meadows on the South Fork of Kings River several thousand feet higher up, but I find no distinct characteristics, though the spermatheca appeared more twisted. Among the specimens were a few of *Telmatodrilus Vejdovskyi*, for which I am thus able to note a new locality.

PLATE XXX.

PLATE XXX.

PHŒNICODRILUS TASTE.

1A. Semi-diagrammatic view of the body in a longitudinal vertical section, showing the position and proportion of the various organs. *phx.* pharynx. *sl. gl.* salivary glands. *sp. gl.* septal glands. *sp. s.* sperm-sacs. *cl.* clitellum. *h.* hearts and dorsal vessel. *œ.* œsophagus. *spth.* spermatheca. *dvt.* diverticulum of œsophagus. *t.* testes. *si.* sacculated intestine. ♀. ovipore. *ov.* ovary. ♂ male pore.

1B. View of the interior organs, the body-wall being laid open from above. On the right hand side the sperm-sacs have been removed in order to show the underlying organs. The letters indicate the same as in figure one. The shaded part of somites xiv to xviii indicate the clitellum proper. *ac.* accessory copulatory papillæ around the outer setæ in somite xiv.

2. Longitudinal section through some of the anterior somites, from a section lateral to the œsophagus, illustrating the connection between the septal and supra œsophagal glands and their ducts, which all open into the upper wall of the pharynx. *s.* septum. *bd. w.* body-wall. *sl. gl.* salivary or supra pharyngeal glands. *s. gl.* septal glands.

3. Spermatheca in outline.

4 The spermduct and male pore viewed from above or from the interior of the body. Both are covered by the longitudinal muscles, as well as by numerous arciform muscles.

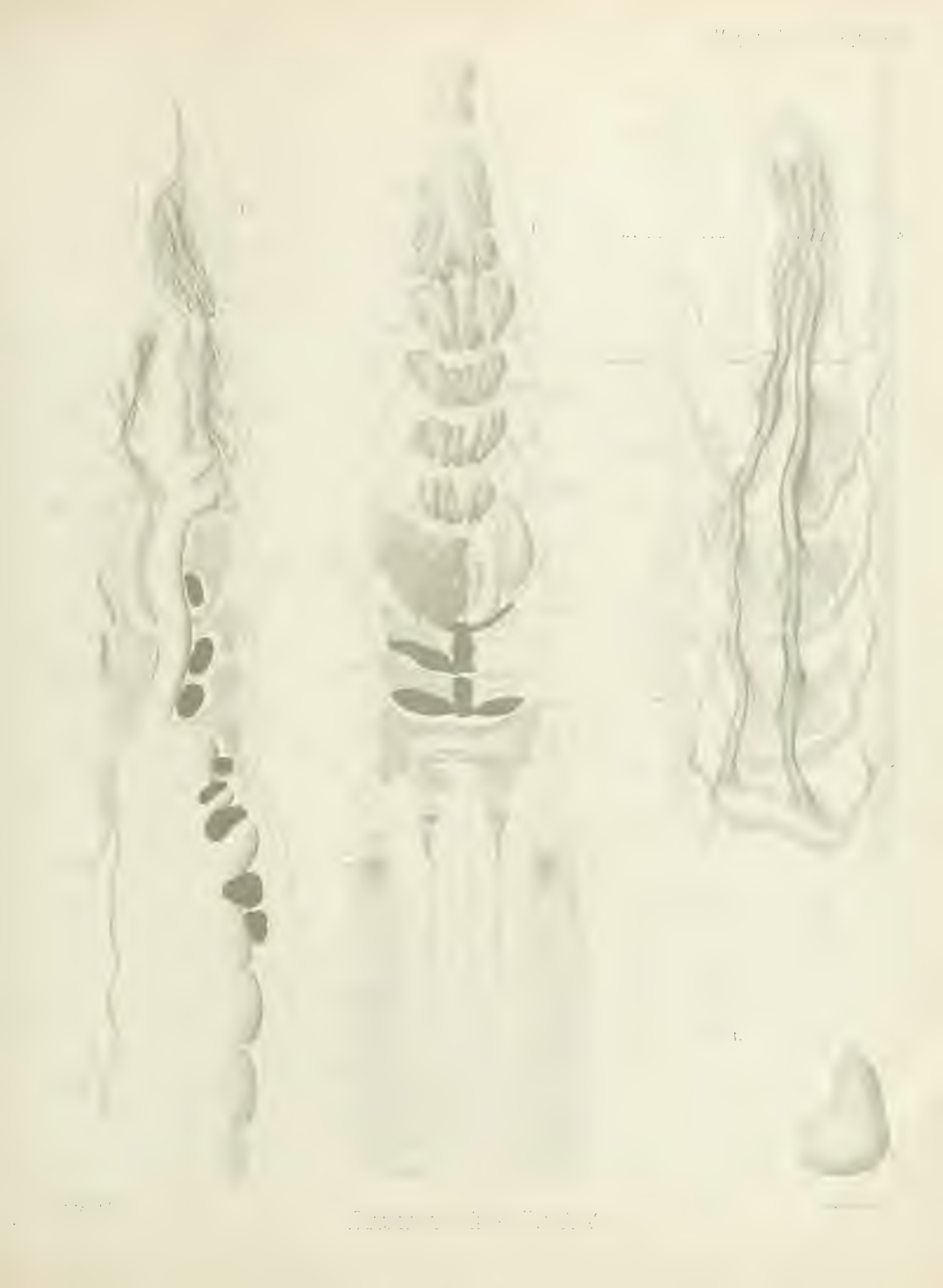


PLATE XXXI

PLATE XXXI.

PHŒNICODRILUS TASTE.

5. A transverse section of the body-wall in somite xvii, through the male pore showing the degenerated atrium and the wider upper part where enters the spermduct. These latter have just been fused and enter the pore as one single duct. *cl.* clitellar cells. *hy.* hypodermal layer. *cl.* collar of epithelium of the atrial chamber. *ac. m.* arciform muscles. *f. sp.* fused spermduct just entering the atrial chamber. *l. m.* longitudinal muscular layer of body-wall. *tr. m.* transverse muscular layer of body-wall. ♂ male pore.

6A. The section nearest anterior to the former, showing the spermducts just as they enter the atrial chamber. The spermducts are not yet fused. Figures indicate the same as in the preceding figure. *sp.* spermducts just before being fused together.

6B. Section nearest anterior to the former showing the two spermducts, etc.

7. The three somites xvi, xvii and xviii viewed from the interior, the alimentary canal and nerve-cord having been removed, as well as nephridia.

8. One of the setæ magnified, the same relative proportion as that used in my paper on Ocnerodrilus.

9A. One of the nephrostomes seen in front views. When in proper position the face of the rosette stands parallel to the septum. *r.* rosette proper. *n.* neck with very large glandular cells. *n. d.* narrow duct. *s.* septum. *f.* fold of the main nephridial body.

9B. Nephrostome seen from the side, the position when the body is opened and spread out. Letters indicate the same as in the last figure.

10. One of the muscles connecting septal glands with body-wall, in cross-section. *s.* septum. *m.* muscular fascicle.

11. One of the posterior nephridia seen under a low magnifying power in order to show the peritoneal covering and the general outline of the canals in the lower peritoneal lobe. *a. f.* anterior fold of canals. *p. f.* posterior fold of canals. *spu.* the partially free spur. *s.* septum. *nst.* nephrostome. *np.* nephropore. *w. t.* the wide tube leading to the nephropore. *br.* bridge connecting the spur with one of the folds. *u. l.* upper lobe of peritoneal cells which does not contain any canals. *c. l.* connecting lobe. *l. l.* lower lobe. The two peritoneal lobes vary greatly in shape and hardly two are found exactly alike, though the general form is the same in all.

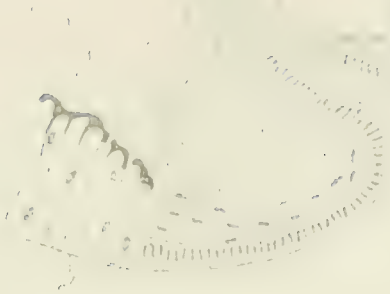


PLATE XXXII.

PLATE XXXII.

PHŒNICODRILUS TASTE.

12. One of the posterior nephridia more highly magnified, to show the course of the canals.

13. Phœnicodrilus taste, natural size, the worm having first been killed gradually with increasing strength of alcohol. Largest specimen.

14. Section of the intestine at the point of connection with the diverticula, in order to show the arrangement of the blood vessels and the subdivisions of the diverticula. This figure is taken at the junction and shows the diverticulum as one chambered, and with a large blood vessel penetrating the diverticulum from the outside. This blood vessel comes from the dorsal vessel. This and the following five figures are outline drawings from slides, but the details of less importance are not filled in. *bl.* small vessels in the vascular layer of the alimentary canal. *dv.* diverticulum. *bl. v.* large blood vessel penetrating the diverticulum from the exterior. *ep.* epithelial lining of the intestine. *m. l.* muscular layer of the intestine.

15. Section closely following, or anterior to the former, showing the diverticulum as one chambered and with a division of the blood vessels into smaller ones. Letters indicate the same as in the former figure.

16A. A section of one of the diverticula a little anterior to the former, the organ is yet one chambered, and a large blood vessel is seen on the left side or the side nearest the intestine. *l. bl. v.* very large vessel. *bl. v.* small vessels in the wall of the diverticulum.

16B. A section anterior to the former, showing the beginning of the subdivision of the diverticulum.

16C. A section next anterior to the former, showing the diverticulum two chambered.

16D. A section near the center of the diverticulum, showing six interior chambered and a multitude of blood vessels.

16E. A part of diverticulum more highly magnified, showing nuclei and striated cycloplasm.

16F. Section of alimentary canal.

PLATE XXXIII.

PLATE XXXIII.

PHŒNICODRILUS TASTE.

17. Longitudinal section of the alimentary canal (œsophagus), in vi. *ep.* inner lining epithelium. *gl.* glandular cells. *bl.* blood sinus. *m.* the two muscular layers. *pt.* peritoneal epithelium.

18. Longitudinal section of the pharynx, showing the glandular ducts and ductules penetrating the pharyngeal epithelium. *cl.* ciliated surface. *n. ep.* nuclei of epithelium. *dus.* ductules. *duct.* large duct from the pharyngeal glands above the œsophagus. *œ. ep.* œsophageal epithelium joining the pharyngeal ciliated epithelium.

19. Section of the body through one of the clitellar somites, a diagrammatic view, to show the relative size of the different layers of the body-wall. *d. v.* dorsal vessel. *s. i.* saculated intestine. *m. l.* the muscular layers. *cl. c.* clitellar cells. *sp. d.* spermducts. *v. v* and *n. c.* ventral vessel and nerve cord.

20. A diagrammatic section of the body in somite ix showing the relative size, etc., of the diverticula and the layers of the body-wall. *d. v.* dorsal vessel. *sp. s.* sperm-sacs in somites ix and x. *div.* diverticula of the intestine. *v. v.* ventral vessel. *n. c.* nerve cord.

21. Section of body-wall of a non-clitellar somite. *g. c.* unicellular glands. *s. c.* supporting cells. *t. m.* transverse muscular layer. *l. m.* longitudinal muscular layer. *pr.* peritoneum.

KERRIA McDONALDI.

23. Nephridium of *Kerria McDonaldi* from one of the somites closely posterior to the clitellum. *pr. s.* peritoneal sac with nuclei. The posterior end of this sac is not furnished with blood capillaries. *c. bl.* capillary blood vessels, spreading principally through the peritoneal sac. *a. l.* anterior lobe. *p. l.* posterior lobe. *nephr. st.* nephrostome. *nephr. pr.* nephropore. *w. d.* wide duct outlet. *n. d.* narrow duct. *nec.* neck of the nephridium. *br.* bridge. *spr.* spur. *s.* septum.

PONTODRILUS MICHAELSENI.

24. A specimen, natural size, having been slowly killed and extended. One of the largest specimens, the majority being only one-half as large.

25. The three anterior somites seen from the side. *pr.* prostomium. *per.* peristomium.

26. The anterior part of the worm more highly magnified, ventral view. *cl.* clitellum. ♂ male pore. *spth. p.* spermathecal pores. *ov. p.* ovipore. *c. pr. m.* cushion where ends the fan-shaped fascicle of prostate or arciform muscles. *c. c.* exterior copulatory cushion.

27. Part of the body-wall laid open and spread out to show the relative distances of the setæ, the numerals indicating the number of the seta. The ventral nerve cord is indicated.

28. One of the setæ highly magnified.

PLATE XXXIV.

PLATE XXXIV.

PONTODRILUS MICHAELSENI.

29. A somewhat diagrammatic view of the anterior somites seen in longitudinal section. *br.* brain. *mo.* mouth. *ph.c.* pharyngeal cavity. *phx.* pharynx. *m.* muscular strand connecting pharynx with the body-wall. *sl. gl.* salivary or pharyngeal glands opening by ducts in the pharynx, the ducts being supported by muscular strands (stained yellow). *ss. gl.* smaller gland; connected with blood vessel. *gl.* glands connected with the lateral vessels. *œ.* œsophagus. *d. v.* dorsal blood vessel. *s.* septa. *spth.* spermathecæ, and their diverticula. The lower end of the spermatheca is greatly enlarged, forming propulsory bursa. *spth. p.* spermathecal pore. *t.* testes. *ov.* ovaries. *ovd.* oviduct. *c. r.* ciliated rosettes. *h.* hearts. *sp. s.* sperm-sacs. These sacs are principally ventral to the œsophagus. *nephr.* nephridia, the most anterior one is found in somite xiii. *cl.* clitellum. *gl. cr.* glandular crop in shape resembling a gizzard. *s. i.* sacculated intestine. *pr.* prostate. *δ* the muscular duct of the prostate cut through. *c. c.* copulatory cushion. The dotted line indicates the outlines of the duct as they appear in other sections.

30. Section through the posterior part of the pharyngeal glands, showing the arrangement of the glands, ducts, muscles and blood vessels, all in vertical section. *œ.* œsophagus. *ep.* inner epithelial lining. *m. œ.* circular œsophageal muscles. *m.* muscular strands. *phx. gl.* pharyngeal gland. *d. v.* dorsal vessel.

In this figure the glands are stained violet, the muscles appear as yellow and the ducts are dark violet. The blood vessels are black (Corosive sublimate, abs. alcohol, orange G. amm. hæmatoxylon. Thus in xylol. This and the following five figures are all drawn from sections treated in the same way.)

31. A longitudinal section of a lobe, showing the general arrangement of the glands and ducts. *duc.* ducts from the gland, leading anteriorly to the pharynx. *gl. c.* glandular cells. *bl. gl.* blood glands. *m.* supporting muscular strands. *bl. v.* blood vessels.

32. A small glandular lobe more highly magnified. The letters indicate the same as in the preceding figure. The nuclei are stained yellowish with orange G. The secretion of the cells is precipitated? and stained dark violet with amm. hæmatoxylon.

33. A part of a gland, with supporting muscles.

34. Two sections of muscular strands, showing the connection with the ducts in which the secretion has been stained deep blue.

35. One of the glandular cells with nucleus stained yellow. The vacuoles (*va.*) are white, the protoplasm grayish, while the secretions are stained deep bluish-violet.

36A. The proximal end of two glandular ducts where they penetrate the epithelial lining of the pharynx, near its dorsal side, showing the ductules or end ducts leading between the epithelial cells. *bl.* blood vessels. *m. ph.* supporting muscles for the ducts connecting with pharynx. *t. m.* transversal muscles cut across. *gl. d.* glandular ducts leading from the gland at the distal end beyond the pharynx. These ducts are the largest and collective ones, having received the secretion from many smaller ducts. *ep.* epithelial cells lining the pharyngeal cavity. *gl. dt.* glandular ductules passing between the former into the pharyngeal cavity. *s. gl.* two of the smallest of the salivary glands, a few of which are found at the periphery of the pharynx.

36B. A longitudinal section of one of the small septal glands, one pair of which is found in v, vi, vii, viii, ix. *c. bl. v.* connecting blood vessel between the ventral vessel *c. bl.* vi and the dorsal vessel. This vessel is cut in two places, the one marked *c. bl.* vii being nearest to and just below the œsophagus (*œ. v.*) the ventral outline of which only is figured diagrammatically. *s.* septum, outline of, between vi/vii. *gl.* small glands, a few of which surround the somewhat larger septal gland. *s. gl.* the largest septal gland. *w. c.* wandering or perigastric corpuscles. *d. t.* discharge ducts from glands, probably connecting with the pharynx.

37. Cross-section of an immature specimen, through the intersegmental groove between somites xvii/xviii, just anterior to the copulatory cushions. In this section no clitellar cells have yet developed on the ventral side of the body. *hy.* hypodermis. *t. m.* transverse muscular layer. *l. m.* longitudinal muscular layer. *neph.* nephridium. *s. a.* septum between xvii/xviii. *m.* muscles connecting the glandular part of the spermatheca with the body-wall. *gl. pr.* glandular part of the prostate. *spd.* the sperm-duct just entering the glandular prostate. *m. pr.* muscular part of the prostate. *v. nc.* ventral nerve cord. *s. i.* sacculated intestine.

38. Cross-section of the body of an immature specimen, through somite xviii, the section passing through the copulatory cushions and through a part in which the clitellar cells on the ventral side of the body are already developed. *a. m.* arciform muscles connecting the copulatory region with the dorsal part of the body-wall. *cl. c.* clitellar cells developed in this somite only on the ventral side, never extending to the dorsal side even in fully mature specimens. Other letters indicate the same as in the preceding figure.

39. Cross-section through somite xiii close to the anterior septum. The clitellar cells are here fully developed. *s.* part of septum between xii/xiii. *cl. c.* clitellar cells, only developed dorsally. *v. cl.* ventral termini of the clitellar cells. *ov.* ovaries. *spd.* spermduct. *t. i.* tubular intestine. *dv.* dorsal vessel. *h.* hearts.

PLATE XXXV.

PLATE XXXV.

PONTODRILUS MICHAELSENI.

40. Cross-section through somite xvii of a mature specimen showing the development of the clitellar cells on the dorsal and lateral sides of the clitellum. *v. cl.* ventral termini of the clitellar cells. *d. v.* dorsal vessel. *s. i.* sacculated intestine. *neph.* nephridium. *gl. pr.* glandular part of prostate. *pr. m.* muscular part of prostate. *m.* muscles connecting the prostate with the body-wall. *t. m.* transverse muscles. *l. m.* longitudinal muscles. *cl.* clitellar cells. *v. cl.* ventral termini of the clitellar region.

41. Cross-section through a strongly contracted, fully matured specimen, through somite xviii, showing the copulatory cushions as fully developed, as well as the clitellar cells on the ventral side. Unfortunately the only fully developed specimen at my disposal had been badly contracted, hence the cells appear smaller than they would have done in properly prepared specimens. *c. c.* copulatory cushions. *a. m.* arciform or fan-shaped muscular strands, which contract the copulatory region. *i. t. m.* interior transverse muscular strand, ending respectively in the copulatory cushions and in the projecting ventral lobes of the body. Other letters as in the last four figures.

42. The body-wall viewed from the inner side of somites xvii, xviii and xix, showing the genital region of the left side. *pr. m.* prostate muscles connecting this organ with the body-wall. *a. m.* arciform muscles connecting the copulatory cushion with the upper body-wall. *c. c.* copulatory cushion. *sp. m.* muscles connecting the body-wall with the prostate at the junction with the spermduct. *sp. d.* spermduct. *1 and 2 s.* first and second seta. *v. c.* ventral nerve cord. *gl. pr.* glandular prostate. *m. pr.* muscular prostate. *s. m.* smaller muscles, fan-like arranged, confined entirely to the copulatory cushion. *sp. d. p.* spermiducal pore overlaid by muscles. *s.* septa.

43. A somewhat diagonal longitudinal section through the body-wall and copulatory cushion in somite xviii. The section is parallel with the muscular fan of arciform muscles, passing through the copulatory cushion near but not through the body-wall. Illustrating the arrangement of the muscular strands around the prostate in the vicinity of the male pore. The letters indicate the same as in the preceding figure.

44. A longitudinal section through the copulatory cushion and the body-wall, the section being almost vertical. *pr.* prostate, just leaving the arciform muscles, and immediately before bending down towards the prostate pore. *m.* muscles connecting the prostate with the body-wall. *a. m.* the entrance of the arciform muscles into the copulatory cushion.

45. A horizontal section of the body through somite xviii and the copulatory cushions, showing their size and position, etc.

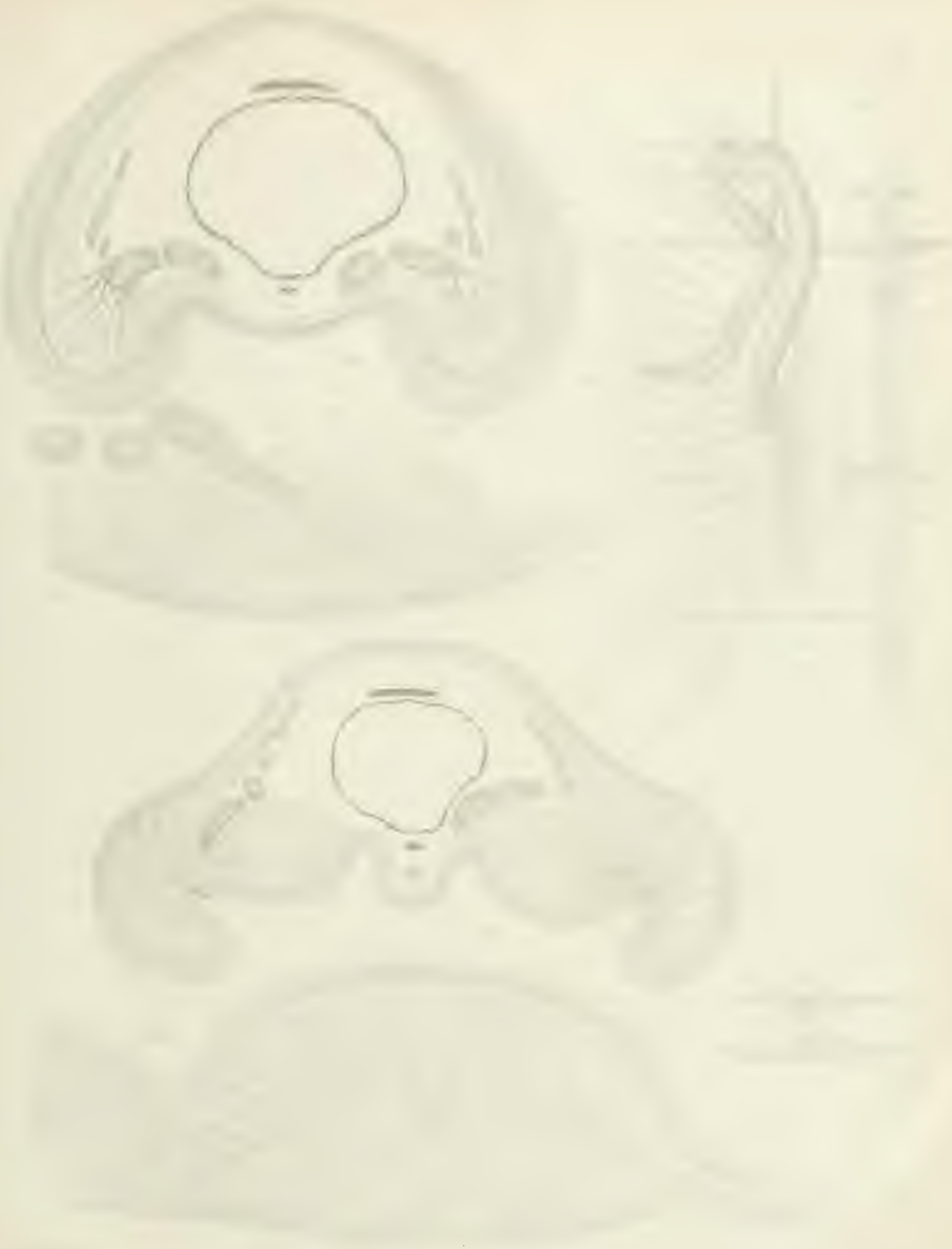


PLATE XXXVI

PLATE XXXVI.

PONTODRILUS MICHAELSENI.

46A. Section through the rudimentary gizzard or thickening of the intestinal wall in somite v.

46B. One of the circular muscular strands of the former figure.

46C. Section of the alimentary wall adjoining posteriorly to the rudimentary gizzard in somite vi.

47. A longitudinal section through the intestine showing the glandular-crop in somites xiv, xv, xvi, and the beginning of the sacculated intestine in xvii. *d. v.* dorsal vessel. *d. v. c.* connection between the dorsal vessel and the vascular system of the crop. *gl. cr.* glandular crop. *bl. s.* blood sinus in the outer layer of the glandular layer. *gl. c.* glandular cells constituting the bulk of the crop. *clo.* chloragogen cells. *m. l.* the two muscular layers. *t. i.* the end of the tubular intestine or œsophagus.

48. A section of the former more highly magnified, showing the glandular cells which constitute the crop and the branched lumens which are especially pronounced in the outer part of the layer. *l. m.*, *t. m.* the two muscular layers, which here are not more developed than in any other part of the intestine.

49. Cross-section through the glandular crop in the posterior part of the organ in somite xvi. In this section only few of the glandular cells are found.

50. A section anterior to the former, but in the same somite. Here many more of the glandular cells are seen. In these two sections the chloragogen layer is thick and the cells crowded, similarly the ridges of the epithelial cells are high and separated by deep grooves.

51. A similar cross-section through the crop in somite xv. Both the chloragogen cells and the epithelial cells are lower.

52. Another cross-section showing the entrance of a blood vessel from the dorsal vessel into the vascular system of the glandular crop.

53. A part of the glandular cells of the crop more highly magnified showing the structure of the cells and the branched lumens between them. *gl. c.* glandular cells. *l.* lumen. *bl.* blood sinus. *ep.* inner epithelial cells.

54. An oblique section through the surface of the crop showing the two muscular layers, a blood sinus and a few chloragogic cells cut through. The glandular cells immediately below are not delineated.

PLATE XXXVII.

PLATE XXXVII.

PONTODRILUS MICHAELSENI.

55. A spermatheca with its diverticulum seen from interior of the body, when the body-wall is spread out. *spth. p.* spermathecal pore. *d.* diverticulum. *spz.* inner sac-like enlargement where the spermatozoa are massed.

56. A cross-section of the body-wall through the spermatheca near its pore. *v. l.* thin vascular layer or peritoneum. *l. m.* longitudinal muscles. *t. m.* transverse muscles. *hy.* hypodermis. *spz.* spermatozoa. *int. n.* interstitial nuclei. *en.* epithelial nuclei and cells. *c. m.* circular muscles of the spermatheca. *div.* diverticulum.

57. A cross-section of the diverticulum of the spermatheca. *in.* inner nuclei of the epithelium. *ints. n.* interstitial nuclei. *c. m.* circular muscles. *bl.* vascular layer. *gl. c.* exterior glandular layer consisting of a double or triple row of cells.

58. A longitudinal section of the body-wall, somites vii, viii and ix made through the spermathecal pore. *spth. p.* spermathecal pore. *spth.* the lower, enlarged part of the spermatheca, which forms a strongly muscular papilla. *dv.* the junction with the diverticulum. *set.* seta. *l. m.* longitudinal muscles. *t. m.* transverse muscles. *a. s.* anterior septum of somite viii. *p. s.* posterior septum of somite viii.

59. One of the testes.

60. A longitudinal section of one of the testes.

61. An ovary.

62. Longitudinal section of an ovary.

63 Longitudinal section of the oviducal funnel. *s.* septum.

PLATE XXXVIII.

PLATE XXXVIII.

PONTODRILUS MICHAELSENI.

64. Section through the body in somite xi, showing the sperm-sacs and their relative position. *s.* anterior septum. *d. v.* dorsal vessel. *h.* hearts. *œ.* œsophagus. *v. v.* the branched ventral vessel. *sp. s.* the racemose sperm-sacs situated much ventrally of the intestine. *n. c.* ventral nerve cord. *l. m.* and *t. m.* longitudinal and transverse muscles of the body.

65. A cross-section of the same region more magnified. *s.* x/xi. septum between x/xi. *s.* xi/xii. septum between xi/xii. *sp. s.* one of the sperm-sacs. *spz.* spermatozoa. *m. c.* mother cells. *c. r.* ciliated rosette. *m. m.* muscles connecting the septum below the sperm-sac with the œsophagus.

66. A more longitudinal section of the ciliated rosette, showing the muscles and the blood vessels in the thick funnel.

67. Another section through the ciliated rosette, showing the thick layer of blood vessels below the ciliated epithelium.

68. A cross-section through the glandular part of the prostate, near the entrance of the spermduct. *ep.* epithelial cells with round nuclei. *c. m.* circular muscles. *c.* glandular cells. *m.* muscles connecting with the body-wall. *sp. d.* spermduct.

69. Cross-section through the muscular part of the prostate.

PLATE XXXIX.

PLATE XXXIX.

PONTODRILUS MICHAELSENI.

70. Cross-section of the body in somite xi, showing the relative thickness of the septa and body-wall, the septa being very much cupped, showing the œsophagus, etc., of the somite ix, as well as the septum and ciliated rosettes of x. *v. v.* x. the ventral vessel in x where it connects with the hearts. *v. v.* ix. the two forms of the ventral vessel. *gl.* septal gland surrounding the connecting vessels in somite ix. There are five pair of these glands, one each in v, vi, vii, viii, ix.

71A. One of the nephridia isolated. *p. l.* posterior lobe of the peritoneal sac of the nephridium. *a. l.* anterior lobe of the same. *w.* windings of the canals where the two folds meet. *p. f.* and *a. f.* posterior and anterior folds of the canal. *n. p.* nephropore. *n. st.* nephrostome. *spr.* spur with four canals. *br.* bridge. *bl. v.* blood vessels on the nephridium.

71B. Nephrostome isolated. *m.* marginal cells. *w. d.* wide duct. *nec.* neck in which the narrow duct is seen to be branched.

72. An enlarged and somewhat diagrammatic drawing of the course of the ducts, etc., of the nephridium. The letters indicate the same as in the preceding figure. The canals have been represented as further apart than they are in reality, otherwise their course could not have been clearly delineated. When the nephridium is viewed from above mounted in glycerine, the outlines of the canals are only dimly discernible, being greatly obscured by peritoneal cells and blood vessels, neither of which have been delineated. The shape of the neck varies to some extent, in some specimens being much wider than in others.

73. Various forms and sizes of blood-glands from the supra pharyngeal and septal salivary glands. Drawn from paraffine sections, hardened in Formaline, and stained: *a.* orange G. alcohol, Ehrlich's hæmatoxylon amm. *b.* rose aniline in hydrochloric alcohol, Bismark brown, and Ehrlich's hæmatoxylon. The latter combination gives by far the finest results, clearly differentiating the blood from the gland-secretion, this being very imperfectly done by the orange G.

PLATE XL

PLATE XL.

PONTODRILUS MICHAELSENI.

74. Cross-section through the body-wall and through the nephropore and wide duct. The latter is seen to enter the glandular neck of the nephridium (*nec*), its inner duct having been cut twice, these cross-sections being always of unequal width. The section *a* passes through the distal windings of the ducts, the letters in the duct indicating that they belong to the same duct. *c. c.* ciliated canal, always wider than the other. The canal *c.* is a branch or forking of one of the other ducts. At *d.* about an inch of the drawing is left out in order to economize room.

75. Longitudinal section of the nephridium near the windings showing the forkings of one of the canals. *c. c.* is the ciliated larger canal. *b.* is the body of the nephridium, in which are seen the branched canals and lacunes, as well as the branching blood vessels which are held back.

76. Part of the neck in cross-section, a larger magnification of a section similar to *a* 74, showing the branching of the narrow duct *n. d.* The wide duct *w. d. t.* is cut twice; the part marked *w. d.* is the part of the wide duct as it leaves the neck for the exterior pore of the body-wall.

ECLIPIDRILUS FRIGIDUS.

77. A diagrammatic view of the anterior somites of the body, composed from several longitudinal sections. Only part of the vascular system is shown, and none of the nephridia, the principal object being to show the arrangement of the reproductive organs and the shape of the alimentary canal. Sperm-sacs not shown. *br.* brain. *bd.* body-wall. *phx.* pharynx. *c. v.* connecting vessels. *d. v.* dorsal vessel. *v. v.* ventral vessel. *cl.* clitellum. *v. c.* ventral nerve cord. *t.* first and second pair of testes. *spth.* spermatheca. *ov.* ovary. *ovd.* oviduct. *c. r.* inner and outer ciliated rosette. *cl.* clitellar layer of glands. *sps.* spermatozoa. *t.* testes. *chlo.* chloragogen cells. ♂ male pore. *p.* penis. *atr. & pr.* prostate and atrium. *pr. m.* muscular layer of prostate. *pr. g.* glandular part of prostate. *atr.* atrium. *str.* storage chamber for protozoa. *spd.* spermduct. *int.* intestine. *br.* bridge.

PLATE XLI.

PLATE XLI.

ECLIPIDRILUS FRIGIDUS.

78. A diagrammatic figure of the region of the reproductive organs, including somites ix to xvii, showing the arrangements of the reproductive organs. The body-wall is represented as being cut open dorsally and spread out. *br.* the bridge or narrow part of the prostate connecting the wide and lower part with the storage chamber of the spermatozoa. *str.* storage chamber of spermatozoa. The prostate and ciliated rosettes are somewhat stretched, as otherwise they could not be seen both at the same time.

79. Part of the clitellum in transverse section, showing the clitellar glands, the longitudinal and transverse muscular layers.

80A. One of the blood glands or herzkörper.

80B. A single gland cell of the former.

81. A transverse section of the dorsal vessel, showing the blood gland occupying the ventral part of the vessel.

82A. Cross-section of the lower part of the spermatheca, at the spermathecal pore. *bd.* body-wall. *ep.* inner lining epithelium. *m.* muscular transverse layer. *ex.* exterior layer. *l. m.* longitudinal muscular layer of the body-wall. *t. m.* transverse muscular layer of the body-wall.

82B. Cross-section of the distal end of the spermatheca.

PLATE XLII.

PLATE XLII.

ECLIPIDRILUS FRIGIDUS.

83–91. Represent somewhat diagrammatic views of transverse section of the body, respectively through somites iii, iv, ix, x, x, xi, xi, xiv and xv. Of somites x and xi sections from the anterior and posterior parts are shown. The following letters are common and indicate the same in each one of the figures: *v. v.* ventral vessel. *d. v.* dorsal vessel. *int.* intestine. *l. m.* longitudinal muscular layer. *t. m.* transverse muscular layer. *v. c.* ventral nerve cord. *m.* muscles and connective tissue uniting the intestine and body-wall. *sp. s.* sperm-sacs. *c. v.* connecting vessels, cut in various places. *phx.* pharynx, shown to be developed only on the upper side of the alimentary canal.

84. The intestine is here seen only to be connected with two superior muscular fascicles with the body-wall. The connecting vessels between the ventral and dorsal vessels are covered with glandular cells, the contents of which stains deeply with hæmatoxylon, and are of a different nature from the chloragogic cells.

85. Section through the first clitellar somite ix. *cl.* clitellar layer. *spth.* spermatheca. *spz.* spermatoza.

86. Section through somite x. In this specimen both the spermatheca project into somite x. The blood vessels which are seen in the sperm-sacs and surrounding the spermatheca are the anterior part of the anterior pair of lateral vessels, which project no further than here.

87. Section through the posterior part of x cutting through the atrium and penis. The ciliated rosettes were not seen in this section, only some parts of the spermduct. The blood vessels seen surrounding the penis and atrium are the anterior parts of the posterior pair of lateral longitudinal vessels.

88. Section through somite xi, close behind the anterior septum, showing the middle part of the outer ciliated rosette cut through. The other rosettes having been torn were not seen on the section. The spermducts are seen as a small circle, one on either side of the prostate.

89. Section through the posterior part of somite xi. The outer spermducts are seen as situated further down, approaching each other, the approach being yet closer in the next section.

90. Section through somite xiv. The prostate being bent zigzag is seen as cut in three different places. At *a* the part anterior to the very narrow part or bridge is seen cut. At *b* this very narrow part and at *c* the posterior part or storage chamber where the spermducts are seen entering the chamber.

91. Section through somite xv. The storage chamber is cut close through its anterior end and is seen surrounded by a thick layer of prostate glands.

92. Cross-section of the atrium below its junction with the prostate. *gl.* small prostate glands penetrating the outer muscular layer. *m. s.* muscular layer. *tube* tube winding in the inner layer of fibrous tissue. *n.* nuclei of lining layer, boundaries of the cells not distinct probably on account of maceration. A few nuclei only are seen in the fibrous mass, which is much thicker in the center surrounding the tube.

93. Cross-section of the prostate proper in somite xii. *gl. s.* small surface glands penetrating between the longitudinal muscular layer. *m. s.* longitudinal muscular layer composed of fascicles or plates of strands. *t. m.* transverse muscular layer. *gl. c.* thick glandular layer of one row of cells. *l. ep.* lining ep. of cells. *spz.* spermatozoa.

94. Cross-section of the narrow part or bridge of the prostate. The layers are the same as in the preceding figure, but of different relative thicknesses. Letters as in preceding. *sp.* sperm ducts. *out. m.* outer layer of muscles, running in different directions.

95. Cross-section of the storage chamber in somite xv, posterior to the entrance of the spermducts, but very close to it. *sp. d.* spermducts. *gl. s. l.* large surface or prostate glands. *gl. s. s.* small surface or prostate glands. *m. s.* longitudinal layer of muscles. *t. m.* transverse muscles. *ep.* lining epithelium with large nuclei.

96. A somewhat oblique section of the posterior part of the bridge, near its junction with the storage chamber, but anterior to the entrance of the spermducts, showing the relative size of the layers and the increased epithelium in the anterior part. *br.* posterior part of bridge, near its widening. *ep.* lining epithelium. *pr. gl.* prostate glands. *l. m.*, *t. m.* longitudinal and transverse muscular layers, both cut obliquely. Both the transverse muscles and the epithelium are thickened towards one end.

PLATE XLIII.

PLATE XLIII.

ECLIPIDRILUS FRIGIDUS.

97A. Cross-section of the neck of a nephridium.

97B. Section of the long duct.

97C. Nephrostome and part of duct.

99A. Section of the lower part of the male organ, slightly oblique to the longitudinal axis of the penis, but parallel to the atrium. *atr.* atrium. *f. t.* fibrous tissue. *in.* inner lining of the atrium with long oval nuclei. *l. ms.* longitudinal muscular layer of atrium. *t. ms.* transverse muscular layer. *gl.* small glands scattered over the surface of atrium and prostate. *spd.* spermduct. *sep.* part of the septum between x/xi. *sphxt.* circular muscles or sphinxter. *gl. c.* large glandular cells composing the collar. *m. p.* muscular plates, to which the longitudinal muscles of the atrium are joined. *tube.* penis tube. *ps.* penis sheath. *pre.* preputium. *bd.* body-wall.

99B. Section of inner penis tube of the former figure.

100. The lower end of the male organ, atrium and prostate in somite x, xi, somewhat diagrammatically figured, in order to show the different layers, penis, etc. *pr.* prostate proper, projecting somewhat into x. *s.* septum. *t. pr.* terminus of prostate. *pr. m.* muscular layer surrounding the prostate. This layer contains numerous glands. *pr. gl.* glandular layer of long flask-like cells. *ep.* inner lining epithelium. *tube* tube running from prostate through penis and atrium—a penis lumen, with thick walls connected with the atrial wall by numerous strands, which on the upper part form a thick layer surrounding the tube, but lower down becomes thin, at least consisting of only few strands. *col.* collar surrounding posterior part of penis. *p.* penis, projective part. *pre.* preputium, eversible. *bd.* body-wall. *f. t.* fibrous tissue.

101. A somewhat larger view of the lower end of the penis. Both this and the former drawing are made from dissections mounted in gum-thus and viewed from above. Letters indicate the same as in fig. 92.

PLATE XLIV.

PLATE XLIV.

ECLIPIDRILUS FRIGIDUS.

102. The central part of the dissected prostate and male organ, as seen when mounted in gum-thus. This figure represents the narrow part of the prostate or tube, connecting the lower or glandular part with the upper or storage part. The two spermducts are marked much more strongly than they appear and are more spread or separated. The drawing represents views at two different foci. Zeiss C. Eyep. 3, *t.* 165. *a.* the posterior part or storage chamber in which the spermducts open at *j. sp.* The anterior end of this chamber is lined by a very thick epithelium, which however rapidly diminishes in thickness backwards. *b.* the very narrow part connecting the posterior storage chamber with the anterior prostate. *c.* the anterior prostate. *out.* outer layers of the storage chamber and prostate, surface views. *lu.* lumen of storage chamber. *lum.* lumen of prostate. *ep.* very thick epithelium at the anterior end of the storage chamber. *j. sp.* junction of spermducts and storage chamber. *l. v.* lateral longitudinal blood vessels. *se.* septum between xiv/xv. *spt.* septum between xv/xvi. *spd.* spermducts. *br.* narrow part of prostate or bridge. *gl.* glandular layer of prostate. *ept.* lining-epithelium of prostate,

103. The anterior end of the storage chamber, dissected, mounted in gum-thus. The focus is set on the inner concave surface, showing the junction of spermducts and bridge with the storage chamber proper. *sp.* the pores where enter the two spermducts. *outer.* coats of muscles and small prostate glands of the storage chamber. *br.* bridge or narrow part of the prostate.

104. Longitudinal section of the body-wall, showing posterior ciliated rosette, etc., behind the male pore.

105. The inner end of the former more highly magnified. The letters indicate the same as in the last figure. Only some of the larger prostate glands are figured. Zeiss C. Eyep. 3.

106. A part of the former more highly magnified. Zeiss Hom. Im. 1-12, Eyep. 3-155. The letters indicate the same as in fig. 104. This section is more parallel with the longitudinal axis of the organ. The cell walls of the epithelial cells were not distinct, probably on account of maceration.

PLATE XLV.

PLATE XLV.

ECLIPIDRILUS FRIGIDUS.

107. A transverse section, the storage chamber more highly magnified. Zeiss Hom. Im. 1-12 Eyp. 3. 155. *pr. gl. l.* large prostate glands. *pr. gl. s.* small prostate glands. *l. m.* longitudinal muscles, arranged in strands. *t. m.* transverse muscles. *n.* nuclei of inner lining epithelium.

108A. A dissected ovary.

108B. A ripe ovum.

109A. A dissected oviduct.

109B. Longitudinal section of the body-wall, at the ovipore, showing the latter to be situated in the intersegmental groove.

110 to 124. Various and successive stages of development of spermatozoa.

110. A resting spermatogonium (spermatospore) from the testes.

111. A spermatogonium from the outer edge of the testes ready to fall off into the sperm-sac. The chromosomes of the nucleus have begun to develop into winding rods.

112. Nucleus from a spermatogonium from the sperm-sac.

113. Spermatogemme (spermatosphere or spermpolyblast). The spermatocytes (spermatoblasts) are surrounding and attached to a central, non-nucleated cytophore (or spermblastophore).

114. The same shortly before division of the spermatocytes.

117. A spermatogemme in the next last stage of development. The spermatocytes have through division reached their final number. The cell divisions are indistinct. The nuclei are globular with scattered chromosomes.

118. A further developed or next last stage of the spermatogemme. The nuclei have assumed an ovoid shape, staining very dark with saffranin.

119. A part of a spermatogemme, last stage. The nuclei have again diminished in size and become perfectly round, previous to growing out into spermatozoa.

120. Part of spermatogemme in which the nuclei of 119 have begun to grow out into spermatozoa.

121. A fully developed spermatogemme with grown spermatozoa attached to the cytophore.

122. The same in a state of dissolution, the spermatozoa detaching themselves.

123. Spermatozoa fully developed, the nuclear end being only slightly thicker than the other part of the body.

124–125. Sections of fully developed spermatogemmes, showing spermatozoa in cross-section, they having gradually diminished in diameter since the nuclei were first concentrated (fig. 119), but having proportionately grown in length.

126. Nuclei from 113, 117, 118, show their relative size.

127–129. Yolk sac with yolk cells.

127. The whole sac in section. Zeiss C.

128. Yolk cells without granulation.

129. Further developed yolk cells with granulation.

KERRIA McDONALDI.

130A. Longitudinal section of the alimentary canal of *Kerria McDonaldi* in the somite next posterior to the male aperture, showing unicellular glands alternating with ciliated epithelial cells. *gl.* unicellular glands.

130B. A more highly magnified part of the former, showing one of the unicellular glands, surrounded by common epithelial cells, also rudimentary glands. *r. gl.* rudimentary glands. *gl.* large gland. *p.* its pore. *ep.* epithelial cells. *bl. v.* blood-lacune. *l. m.* longitudinal muscles. *t. m.* transverse muscles.

PACIFIC COAST OLIGOCHÆTA.

II.

Benhamia, Acanthodrilus, Aleodrilus, Sparganophilus, Deltania, Phœnicodrilus.

BY GUSTAV EISEN, PH. D.

The following genera and species are treated of in this paper:

Benhamia nana n. sp.
Benhamia mexicana Rosa.
Benhamia Bolavi Michaelsen.
Benhamia palmicola n. subsp.
Benhamia papillata n. sp.
Benhamia rugosa n. sp.
Benhamia octonephra Rosa.
Benhamia Godeffroyi Michaelsen.
Benhamia malayana Horst.
Benhamia floresiana Horst.
Benhamia Annæ Horst.
Acanthodrilus tamajusi n. sp.
Acanthodrilus Vasliti n. sp.
Aleodrilus Keyesi n. sp.
Sparganophilus Benhami n. sp.
Sparganophilus Smithi n. sp.
Sparganophilus sonomæ n. subsp.
Sparganophilus Eiseni Smith.
Sparganophilus guatemalensis n. subsp.
Sparganophilus carneus n. sp.
Sparganophilus tamesis Benham.
Deltania Troyeri var. **crassa** n. var.
Deltania Troyeri var. **lagunæ** n. var.
Phœnicodrilus taste Eisen.
Phœnicodrilus tepicensis n. sp.

BENHAMIA Michaelsen.

The genus Benhamia was for some time considered a typical African genus, and when later on a few extra-African species were found it was supposed that these were recent emigrants, which had become more or less cosmopolitan. Of American species two are known from Mexico and Venezuela, viz.: *B. Bolavi* and *B. mexicana*, and one, *B. octonephra* Rosa, has been described from Paraguay since this paper was presented for publication. This latter species appears very nearly related to *B. rugosa*, described below, but differs through the absence of penial setæ.

The discovery of species of Benhamia at Miraflores, in the Cape Region of Baja California, in a locality to which plants of any kind have rarely if ever been introduced directly from foreign countries, would indicate that this genus has possessed representatives on American soil for ages past, and that we really must consider these American species as truly endemic. A final answer to this question of habitat must be deferred to a future time, when more researches will have been made as regards the distribution of these and other Benhamia species, as it is probable many more will be found on this continent. A difficulty, which besets us from the beginning, is, that so few species have been properly delineated, all descriptions having been made chiefly with a view to distinguish the species from others already known, while with proper delineations of the various organs, we would in all probability be able to make a satisfactory comparison between species new and old. I have received much aid from Dr. W. Michaelsen, of Hamburg, who has described more Benhamia species than any other investigator, and who has written extensively upon this genus. He has kindly placed at my disposal several species of African Benhamia, as well as of *B. Bolavi*, for comparison with forms found by me. This has enabled me to point out several important differences between *B. Bolavi* and *B. palmicola*, which are sufficient to distinguish these as subspecies from each other, as well as from others previously known. At the end of the descriptions of the various new species I append a table of characteristics, etc., between species which may be confounded with our present ones, either on account of similarity of some characters or because of their geographical distribution in the Malay archipelago, or in America.

As we now understand the distribution of this genus, the species are divided as follows: America, 7 species; Malay archipelago, 3 species; Africa, 25 species; West Indies, 2 species.

It may, however, be remarked that *B. rugosa* described below is of uncertain habitat having only been found in a hot-house, to which it had been imported from unknown country.

Considering our various new species of Benhamia this genus may be characterized as below:

Benhamia Michaelsen.

Acanthodrilid oligochæta. Setæ strictly paired, ventral and lateral. Clitellum generally incomplete, but in some species complete in some somites. Two gizzards in succeeding somites. Calciferous glands generally three pairs, but sometimes only two pairs, very distinctly set off from the tubular intestine. Nephridia in

respective species either diffuse or micronephridia arranged in three, four or more rows on either side, some species showing several gradations. Spermatheca two pairs, contracted at center with one or more small diverticula, Penial setæ nearly always present. Generally small, tropical worms.

DEFINITIONS OF AMERICAN SPECIES OF BENHAMIA.

Benhamia nana n. sp.

DEFINITION. *Size Length 20 to 30 mm.; number of somites 110; skin strongly pigmented. First dorsal pore between iii/iv. Prostomium very swollen and overlapping. Clitellum complete in central somites. Penial setæ, the largest with 12 or more bristles. Common setæ, distance between the dorsal couples about equal to that between the ventral couples. Oviducts, two pores, open in front of 1 and 2. Prostate pores not on papillæ. Pharynx situated very far forward. Gizzards in viii and ix. Calciferous diverticula, two pairs in xv and xvi. Sperm-sacs in x and xi. Spermducts thicker at the base in xviii, xvii and xvi. Nephridia in three rows on either side, the posterior with cœlomic mantle. Spermatheca, basal part with one diverticulum, apical part warty and irregular. Typhlosole large, begins in xviii. Color brownish red. Habitat, San Blas, Mexico, at sea level.*

Benhamia mexicana Rosa.

DEFINITION. *Length 30 mm.; number of somites 120. Skin not pigmented. First dorsal pore between iii/iv. Prostomium divides the first somite completely. Clitellum complete in xiii to xxi. Penial setæ not ornamented (?); common setæ, 3 and 4 further apart than 1 and 2. Oviducts, two separate pores in front of 1 and 2, on small papillæ. Gizzards in viii and ix. Calciferous gland 3 pairs in xv, xvi and xvii. Nephridia in 3 rows on either side. Spermatheca with a single short diverticulum. Alcoholic specimen colorless. Habitat, Durango, Mexico, at 2500 meters altitude.*

Benhamia Bolavi Michaelsen.

DEFINITION. *Length 40 to 60 mm.; number of somites 97. First dorsal pore between v/vi. Clitellum incomplete in all somites, xiii to xx. Penial setæ, the largest with five to eight notches, the smaller spoonlike and slightly forked; common setæ couples equidistant. Oviducts open in one single pore on a median papilla in xiv. Gizzard two in vii. Calciferous gland three pairs in xv, xvi and xvii. Sperm-sacs one pair in xi. Nephridia in three rows on either side. Spermatheca, the basal part with a single small diverticulum. Saculated intestine begins in xxi. Color dingy flesh. Habitat, Venezuela (and Hamburg).*

Benhamia palmicola n. subsp.

DEFINITION. *Length 50 to 60 mm.; number of somites 90. Skin not pigmented. First dorsal pore between iv/v. Clitellum incomplete in all somites. Penial setæ, largest with four notches, the smaller one spoonlike and forked; common setæ about equal distance between the dorsal and ventral as between the ventral couples. Oviducts open in one single pore on a median papilla. Gizzards both in viii. Calciferous gland 3 pairs in*

xv, xvi and xvii. Sperm-sacs in xi and xii. Spermducts of even width. Nephidia in 3 distinct rows on either side. Spermatheca basal division globular, equal in size and shape to the apical part, single small diverticulum. A typhlosole. Color reddish flesh. Habitat, Baja California, Cape Region, 1000 feet; Tepic, Mexico, 4000 feet.

Benhamia papillata n. sp.

Definition. *Size 50 to 70 mm. by 2 mm. Number of somites 125. First dorsal pore v/vi. Prostomium divides somite 1 more than one-half, and is much swollen. Clitellum complete, xiii–xx. No ventral setæ in xviii, but setæ 3 and 4 present. Prostate pores on large papillæ, the four papillæ being close together in the sunk clitellar pit. Oviducal pores on a large median papilla, but the pores are separate and on a line drawn between the setæ. Penial setæ, largest slightly hooked with 8 indistinct notches, smallest with a hair-like sigmoid tip. Spermathecæ, the apical-sac not globular, basal part with a swell diverticulum. Sacculated intestine commences in xix. Typhlosole in xx–xiv. Calciferous diverticula 3 pairs in xvi, xvii, xviii; the anterior one is much smaller. Sperm-sacs in x and xi. Nepridia a consists of three distinct lobes, each one with a cœlomic mantle. Color pale flesh, no pigment. Habitat, Tepic, Mexico, 4000 feet.*

Benhamia octonephra Rosa.

Definition. Compiled after Rosa. *Length 20 to 40 mm.; number of somites 85 to 95. First dorsal pore between v and vi. Clitellum incomplete, in xiii to xx. Penial setæ, the larger with six groups of two blunt tubercles; the smaller seta like a scalpel. Common setæ, couples equidistant. Oviducts open into a single median pore on a slight swelling. Calciferous diverticula three pairs in xv, xvi and xvii. Sperm-sacs in xi and xii. Nephridia micronephric in four rows on either side. Spermatheca, basal part pear-haped with a globular diverticulum. Habitat, Paraguay.*

Benhamia rugosa n. sp.

Definition. *Length 30 mm.; number of somites 118. Skin slightly pigmented and corrugated. Clitellum incomplete, in xiii to xx. Penial setæ, largest with five notches; smaller seta forked with prongs of equal size. Common setæ pointed and ventral. Oviducts open jointly in a median pore. Gizzard in vii and viii. Calciferous diverticula in xv, xvi and xvii. Nephridia micronephric in four rows on either side. Typhlosole present. Spermatheca much flatiened. Color reddish flesh. Habitat, California, in hothouse (imported).*

Benhamia Godeffroyi Michaelsen.

Definition. *Length 90 mm. by 4 mm.; number of somites 174. Skin pigmented anteriorly. Clitellum incomplete (xiii) xiv to xx. Penial setæ slender with numerous irregular notches; many setæ in each sac. The curved fossa between the prostate pores with the convex side toward the median line. The anterior prostate largest. Calciferous diverticula three pairs. Nephridia plectonephric. Spermatheca without diverticulum, but with warty protuberance. Color, anterior pale reddish, posterior part gray. Habitat, Hayti (?).*

Table A. COMPARATIVE TABLE OF ALL KNOWN EXTRA-AFRICAN SPECIES OF THE GENUS BENHAMIA. To face page 126.

	nana n. sp.	*mexicana* Rosa.	*Bolavi* Michaelsen.	*palmicola* n. subsp.	*papillata* n. sp.	*octonephra* Rosa.	*malayana* Horst.	*floresiana* Horst.	*Annæ* Horst.	*rugosa* n. sp.	*Godeffroyi* Michaelsen.
Habitat	San Blas, Territory of Tepic, Mexico, at sea level. Strictly tropical form.	Durango, Mexico, 2565 metres above the sea level. Temperate form.	Hamburg, at Bergedorf, imported, and Venezuela (Ude).	Baja California, Cape Region and Tepic, Mexico, 1000 and 4000 feet.	Tepic, Mexico, 4000 feet.	Paraguay.	Malay Archipelago.	Malay Archipelago.	Java.	San Francisco, California, imported.	Hayti (or New Zealand?)
Size	20 to 30 mm.	30 mm.	40 to 60 mm.	50 mm.	50 to 70 mm.	20 to 40 mm.	20 to 30 mm.	35 to 40 mm.	30 mm.	30 mm.	90 mm. by 4 mm.
Number somites	110. Skin strongly pigmented in anterior somites.	120. Skin not pigmented.	97.	90. Not pigmented.	125 (largest specimen).	85 to 95.	95. Skin without pigmentation.	125. Skin without pigmentation.	85. Skin without pigment.	118. Skin slightly pigmented and anteriorly corrugated.	174. Anterior part of body pigmented.
First dorsal pore	iii–iv.	iii–iv.	v–vi.	iv–v.	v–vi.	v–vi.	v–vi or vi–vii.	vi–vii.	iv–v.	v–vi.	
Prostomium	Very swollen and overlapping.	Divides the buccal somite completely (?)	Does not divide buccal segment.	Not very pointed.	Divides partly buccal segment; swollen.		Continued into the buccal segment.	Divides somite I about one-half.	Divides partly the buccal segment.	Divides buccal somite about one-half.	Divides buccal segment somewhat less than ½.
Clitellum	Complete in the central somites, xiii–xx.	Complete, xiii–xxi.	Incomplete in all segments, xiii–xx.	Incomplete in all somites, xiii–xx.	Complete, but ventrally thin, xiii–xx.	xiii to xx, incomplete between the ventral setæ.	Complete in the anterior, incomplete in the posterior somites, xiii to xx.	Incomplete, xiii to xxi.	Incomplete in xiii to xxi.	Incomplete in xiii to xx.	Incomplete (xiii), xiv–xix
Penial setæ	The largest with 12 or more strong bristles.	Not ornamented (Rosa). According to Ude, faintly ornamented with 6 thickenings.	The larger seta with five (or eight B) notches on apex; the smaller is spoon-like and slightly forked, with no denticulation.	The larger seta with four notches, the smaller one spoon-like at apex and forked.	Larger with eight faint notches; smaller with a hair-like sigmoid point.	The larger curved, strongly curved at apex, and with 6 groups of 2 blunt tubercles, the smaller expanded at apex like a scalpel.	The larger seta with 4 broad bristles; the smaller spoon-like, but not forked.	Anterior part much undulated, the smaller seta less so; three small bristles at apex of largest seta.	Undulated, with 12 (about?) slight denticulations or notches. The form of smaller seta doubtful.	Largest seta with five notches; smaller seta forked, with prongs of equal size.	Slender, numerous irregular notches, giving knotty appearance, but no teeth or bristles. Many setæ in each sac.
Common seta	Distance between the dorsal couples about equal to that between the ventral couples.	Setæ 3 and 4 further apart than 1 and 2.	Those on posterior segments larger. The couples equidistant.	About equal distance between the dorsal and ventral as between the ventral couples.	Inner couples wanting in xviii, equidistant.	Strictly paired, all ventral; couples equidistant.	Distance between dorsal and ventral couples about equal to that between ventral couples.	Distance between a dorsal and ventral couple about three-fourths of that between the two ventral couples.	The four couples are ventral and equidistant.	Strictly ventral.	In 4 couples, all ventral.
Oviducal pore	Two pores, open in front of setæ 1 and 2.	Two pores in front of setæ 1 and 2 on small papillæ, which touch with their bases.	One single pore on a large median papilla in xiv.	One pore on a central media papilla.	Two closely approximated pores on a median papilla.	A single pore on median line in xiv, on a slight swelling.	Two distinct pores.	Open in an oval glandular area, pores open separately on line with setæ 1 and 2.	Unknown.	Open jointly in a median pore in xiv.	
Prostate pores	Not on papillæ.	Not on papillæ.	Never elevated.	Not on papillæ.	Each on a large papilla.	In line with ventral setæ.	The depression connecting the prostate pores concave, with the convex part turned toward the median line. An elevated area around the depression.	Not elevated, situated at the corners of a square area.	Depressions connecting pores lunate, with the convex side turned towards median line. Area oval, not square; a ridge borders the grooves.	Anterior prostate pores elevated on papillæ.	The curved fosse between the pores, with the convex side turned towards the ventral median line. The anterior prostate the largest.
Pharynx	Situated very far forward.		Not forward.	Not forward.	Not forward.					Not forwnrd.	
Gizzards	In viii and ix.	In viii and ix.	Two in somite vii.	Two; both in viii.	Two.			Two.	Two in vi and vii.	In vii and viii.	
Calciferous diverticula	Two pairs in xv and xvi.	Three pairs in xv, xvi and xvii.	Three pairs in xv, xvi and xvii.	Three pairs in xv, xvi and xvii.	Three pairs in xv, xvi and xvii.	Three pairs in xv, xvi and xvii.		Three pairs.	xv, xvi and xvii.	Three pairs in xv, xvi and xvii.	Three pairs.
Spermsacs	In x and xi.	In x and xi.	One pair only in xi.	In xi and xii.	In x and xi.	In xi and xii, two pairs.			In ix–xii.		
Spermducts	Thicker in xviii, xvii and xvi.	Not enlarged (?)		Not thicker in any somites.							
Nephridia	In three rows on each side of the median line. The posterior ones with cœlomic cell-mantle. The nephridia in each somite of about the same size. The nephridia on each side about equidistant, but the dorsal nephridia are much further apart from the dorsal median line than from the lateral nephridia. Nephridia *a* open in front of 3 and 4.	In three rows on either side, probably all of the same size. Nephridia *a* correspond to setæ 1 and 2. The nephridia on each side are equidistant, and the dorsal nephridia *c* are as equidistant from the dorsal median line as from the lateral nephridia *b*. With cœlomic mantle.	In three rows on either side; the anterior ones have no cœlomic mantle like those posterior to the male pore. The two lateral nephridia of equal size; the ventral nephridium is much narrower, but furnished with two separate cœlomic mantles, the inner of which is smallest. The nephridia are more separated than in *B. palmicola*.	Arranged in three distinct rows on either side of the median line. Nephridium *a* consists of two unequal parts, the most ventral of which is the smallest. Nephridium *a* is much larger than the other nephridia. The dorsal nephridia far apart. Nephridia *a* open in front of 1 and 2.	In three rows, the posterior ones with cœlomic mantle. Nephridium *a* consists of three lobes, each with a separate cœlomic mantle. The inner lobe is much the smallest. The nephridia are closer, overlapping.	Arranged in four series on either side of the median line; the ventral one corresponds to the dorsal setæ.	The posterior nephridia arranged in 3 groups of delicate tubuli on either side, the internal ones situated near the dorsal setæ.	Arranged in four longitudinal series on each side of the median line.	A network of delicate tubules anteriorly spread over the body area, except for a narrow dorsal and ventral median line. Posteriorly arranged in four rows on either side of median line, and furnished with cœlomic mantle.	Arranged in four rows on either side of median line. Posterior nephridia with cœlomic mantles. Nephridia of nearly the same size. Neph. *d* and *d* about equidistant as *a* and *a*. The most ventral part of nephridium *a* not covered by mantle. Clitellar nephridia much larger than those anterior of clitellum.	Plectorephric condition, but not known in detail, except that they cover the whole of the body-wall except a narrow strip dorsally and ventrally. Stronger in the clitellar somite, where they form a thick covering.
Spermatheca	Basal part with one plain diverticulum. Apical part warty and irregular.	The basal part wide, gradually changing into the apical part. Single short diverticulum.	Basal part with a single small diverticulum. Apical division not globular.	Basal and apical divisions globular, equal in size. Single small diverticulum.	Apical division not globular; dorsal part with a single diverticulum.	Basal part pear-shaped; apical part sac-like, basal part with a globular diverticulum directed forward.	Basal part longest and as broad as the apical part, with a narrow diverticulum.	Basal part the longest, narrow; single pear-shaped diverticulum.	Basal part longest and very narrow, with a narrow diverticulum situated near the contraction.	Apical part smallest. Both parts much flattened. Very small diverticulum.	Spermathecæ with no distinct diverticula, but the smaller basal part with irregular warty protuberances. Anterior spermathecæ the largest. The apical part sac-like, larger and thin-walled. The basal part shorter.
Typhlosole	Very large; begins in xviii.			Typhlosole present, but not very large.	Present in xix–xxiv.					Present.	
Color	Reddish-brown, even in alcohol.	Alcoholic specimens colorless.	Dingy flesh-colored alive; clitellum yellowish or pink.	Reddish flesh when alive.	Pale reddish; no pigment.		Alcoholic specimens colorless.	Alcoholic specimens discolored.	Colorless.	Reddish flesh.	Anterior part reddish; posterior part gray.

DETAILED DESCRIPTION OF NEW SPECIES.

Benhamia nana n. sp.

Figs. 1–42.

Habitat. San Blas, territory of Tepic, Mexico. I found a small number of specimens, of which only two possessed a perfectly developed clitellum, October, 1894. A real tropical form.

Color. Deep reddish-brown and very opaque.

EXTERIOR CHARACTERS.

Size small, 20 to 30 mm.

Somites 110.

Clitellum comprises somites xiii to xx, being complete in the central somites, but incomplete in xiii, xvii, xviii and xix.

First dorsal pore iii-iv.

Spermathecal pores, one pair vii-viii, and one pair between viii-ix, rather close together in a ventral grove.

Oviducal pores open separately in xiv in front of setæ 1 and 2.

Prostate pores, one pair in xvii, one pair in xix, open with penial setæ.

Penial setæ, two in each pocket, the largest of which is furnished with 12 or more bristles.

Common setæ, distance between the dorsal couples equal to that of the ventral couples.

INTERNAL CHARACTERS.

Buccal cavity with a dorsal pocket.

Suprapharyngeal glands with pharynx opening far forwards.

Gizzards in viii and ix.

Calciferous glands two pairs, one in xiv, one in xv.

Septal glands very minute in ix, x, xi.

Sacculated intestine commences in xiv.

Typhlosole very strongly developed in xviii to xxii.

Sperm-sacs two pairs in x, xi.

Ciliated rosettes in x, xi. The lower part of the spermducts in xvi, xvii, xviii is thickened and twice the diameter of the anterior part.

Prostates are straight and tubular, each one confined to one or two somites.

Spermathecæ in vii–viii, viii–ix. The apical part much smaller than the basal part, the latter with a small diverticulum placed high up near the constriction.

Nephridia arranged in three rows on either side of the median line. Pair *a* open in front of the outer couple of setæ, pair *b* and *c* open laterally and dorsally as regards the setæ. The posterior nephridia furnished with a large cœlomic cellular mantle. The nephridia in each somite of about equal size. The nephridia on each side about equidistant, but the dorsal nephridia *c* are much further apart from the median line than from nephridia *b*.

DETAILED DESCRIPTION.

Body-wall. The prostomium with buccal cavity is strongly eversible, forming a bladder-like apex to the body, as is so frequent in oligochæta. Somite i is very narrow, especially laterally, and may readily, when viewed from the exterior, be taken for part of the prostomium.

The body-wall contains the usual layers of which the muscular fibers show the same bipinnate arrangement as in Lumbricus, etc. This arrangement is less regular and pronounced in the anterior somites, but quite plain in the genital and clitellar ones, especially so on the ventral side, immediately below the nerve-cord.

Sense organs of the epidermis. All the species of Benhamia described here possess a continuous row of sense organs, in the equatorial plane of each somite, between the setæ. Outside of this equatorial circle I have not found them anywhere in the epidermis; there, however, they are very plain and prominent, appearing under low power and in longitudinal sections, as a large pellucid spot in the center of each somite. The organ consists of two distinct kinds of cells, a double line of large lunate cells, surrounding a row of sense cells, several layers thick. These lunate cells are generally three or more thick in the row, evidently modifications of the common goblet cells of the epidermis. They do not stain with the ordinary aniline colors, or only so with difficulty, and generally remain transparent and white. These lunate cells run continuously around the somite, and enclose between them bunches of sense cells, which may now and then be seen to penetrate the cuticle (fig. 20). Somewhat similar sense organs have been known in Lumbricus, etc., for considerable time, but have lately been described more in detail by Richard Hesse and F. E. Langdon. The sense organs of Benhamia differ from those of *Lumbricus agricola* (probably a collective name used for some East American Allolobophora) in two prominent points. Presence of the large lunate cells in Benhamia, which are not seen in Lumbricus. The continuous and broad circle of these organs in Benhamia, while in Lumbricus they appear to be much further apart. Unfortunately my Benhamias were collected at a time when no special preparation for nerve structure was feasible, and this made it impossible to work out the details as minutely as desirable. The work had already been finished when Langdon's beautiful paper reached me. Fig. 20 represents a section of the body-wall in somite iv. Letters *org.* signify the sense organ.

Besides these epidermal sense organs I find in all the Benhamias, observed by me, a large zone in the buccal cavity characterized by almost cubical transparent cells arranged in one single row deep, just as the epithelial cells in the pharynx, but of the same nature as the transparent cells in the sense organs of the epidermis. This zone is nearly always folded against itself like a sac, and is of considerable extent, as long or longer even than the pharynx. In certain places apparently scattered about, but principally near the opening of this sac, I find clusters of sense cells of the same structure as those of the epidermis. They are all narrow, do not reach below in the cœlomic cavity, but end in this direction in line with the pellucid cells and connect at the end with nerve fibres. The free ends penetrate above in what ap-

pears as a veritable cuticle, though I can find none above the pellucid cells. In fact the whole structure of these organs is very much the same as the sense organs of the epidermis of the body-wall. In connection with them I may point out the similarity of structure of these organs with those described below in *Acanthodrilus Vasliti*, in the vicinity of the prostates; and with those in the tubercula pubertatis of *Sparganophilus Smithi* and *tepicensis*, in all of which I find the same sense cells.

It remains to add that this pouch-like area of sense cells and glandular cells has previously been observed by both Michaelsen and Horst and designated as a diverticulum of the buccal cavity, but the true nature of the pouch as a sense-area has, I believe, not been previously recognized. *B. Bolavi, malayana* and probably most, if not all other, Benhamias possess this organ of the buccal cavity.

Septa. These are generally very thin, only two being thicker than the rest, viz.: xii–xiii and xiii–xiv. These septa do not strictly correspond with the intersegmental grooves, but are affixed much further back in the somites.

Pharyngeal and *septal glands.* The usual supra-pharyngeal glands are present. They are evidently unicellular and arranged ribbon-like as will be directly described below. The septal glands are found in ix, x and xi, are very narrow and only one cell thick in the row as the former. These glandular masses are much thicker in *B. palmicola*, but not any longer.

Intestine. In all the specimens which I could examine I found the pharyngeal parts strongly everted and protruded to such an extent that it formed the lip or front margin of the body, taking the usual place of prostomium proper. I cannot ascribe this entirely to a simple protrusion of the pharynx, but believe that this part is actually situated much more forward than in other species, as I found it to be the case in every specimen observed. The pharynx was found actually on the outside of the body (figs. 15, 16, 17, 18). The real pharynx, of course, is the zone in which open the supra-pharyngeal glands. The wall of this part is in our present species hardly thicker than those of the buccal cavity and the œsophagus, but it contains the usual arrangement of narrow epithelial cells, between which penetrate the fine ducts from the supra-pharyngeal glands. The ends or discharge pockets of these glands are almost globular or rounded flask-like (fig. 18). The supra-pharyngeal glands are arranged as ribbons, running singly along muscular strands. They differ from similar glands in Pontodrilus, Phœnicodrilus, Ocnerodrilus etc., by their arrangement in single rows, and here and there the duct of a single glandular cell may be followed clear to the discharge pocket (fig. 16). These glands appear to consist of a single cell with a long duct, just as the corresponding glands in Euchytræus, described by Hesse. But to draw the conclusion from this fact, that all the pharyngeal and septal glands are unicellular is, I think, premature. In Pontodrilus, at least, there may be seen plainly numerous nuclei on the gland ducts, which, of course, indicates that we here have a fusion of several cells. The pharyngeal glands in that genus do not show this ribbon-like arrangement as in Benhamia. I could, however, see that some of the smaller glands nearest the pharynx consisted of only one cell, but the majority, and all the large glands, consisted of several cells, the respective

ducts of which finally united into one. In Benhamia I could see no such union, and the single ducts could be followed with great facility to the outlets. Fig. 17 represents some of these cells with three narrow ducts and secreted matter.

Œsophagus, following pharyngeal division, is very long. The upper part, immediately below the pharyngeal gland, is very thin-walled, consisting of only one strand each of transverse and longitudinal muscles, and lined by a very narrow epithelium (fig. 19). Posteriorly the walls of the œsophagus thicken considerably. The two distinct gizzards are in viii and ix, as usually connected by a very thin wall of the same general nature as œsophagus (fig. 7). The muscles of the gizzards are columnar but not bipinnately arranged, the ribbons running parallel with the short diameter of the body (figs. 7 and 21).

The tubular intestine extends through somites x to xiv, being of irregular outline. Sacculated intestine commences in xv, and is furnished with a typhlosole in somites xviii to xxiii, or thereabout.

Epithelial cells of the alimentary canal surround glands of various forms. In the epithelial lining of the gizzard we find club-like glands (fig. 21 *gl.*) consisting each of one (seldom of more) large cell with round nucleus, a narrow duct reaching between the epithelial cells, and ending with a large chamber, in very much the same way as the pharyngeal and septal glands.

In the narrow thin walled part between the two gizzards I find a few clusters of glands (?) similar to those I have described in Argilophilus. At the bottom of the cluster we find a glandular cell, upon which are butting the peculiar lunate cells, which again surround a lumen, which is much wider than in the corresponding organ in Argilophilus (fig. 22 *gl.* and *c.*) The lining of the sacculated intestine and the typhlosole are composed of three distinct kinds of cells, two of which are glandular (figs. 24 and 25.) The common epithelial cells offer nothing of particular interest. The glandular cells are of two distinct kinds (fig. 25). One kind is the one most common in oligochæta (fig. 25 *gl.*) and its enclosed granules are much smaller. The other kind is probably identical with the T-shaped cells described by Benham in Eminiodrilus, though the T-shaped form is not quite so prominent. The granulation is coarse and highly refractive and the distal part of the cell stains intensely, especially with methyl green. The other or first mentioned glands remain at the same time unaffected by this stain. These dark staining cells are much less numerous than the other kind, and are scattered about in a rather regular way. Fig. 24 *b* represents one of the lobes of the typhlosole, showing the absence of glands at the apex as well as the general distribution of the dark staining cells.

Calciferous diverticula. I found in the two specimens dissected and sectioned only two pairs of calciferous glands in somites xv and xvi, but I am unable to say if this will be found constant, as all other species of Benhamia possess three pairs of calciferous pockets, which Beddard claims are characteristic of this genus. Michaelsen's observation that the two diverticula are of different nature is confirmed here, as in the posterior pair no lime crystals were found, either in this or in the other species described below. Also the histological structure of the posterior and anterior

diverticula is distinct. The nuclei of the anterior pair are round while those of the posterior pair are more oval, and the cells of the latter pair are not separated by distinct walls. They contain also numerous vacuoles or bladder-like bodies, some of which deatch themselves from the main body of the organ.

Figures 27 and 28 represent the anterior pair, 29 and 30 the posterior pair of calciferous diverticula seen respectively under high and low power. The posterior pairs only were found covered by chloragogen cells. These differences in structure I also found in the calciferous diverticula of the following species: *Benhamia palmicola* and *rugosa*, and they probably hold good with all the species of Benhamia.

Typhlosole exists in somites xvii or xviii to xxii, and is greatly developed as regards length, width and depth (figs. 7 and 14). It is widest and deepest in somite xix, tapering or diminishing both anteriorly and posteriorly. In the following species the typhlosole is much smaller.

Spermathecæ. The two pairs as usual in vii–viii and viii–ix. The form of the spermatheca and its diverticula may be best understood from the figures 34 and 35. The pores come rather close together in a general groove below the ventral ganglion. There is a muscular and a glandular part, and the spermatozoa were fonnd as usual principally in the diverticula.

Spermducts and rosettes. The only peculiarity of the spermducts is that they are thickened in somites xviii, xvii and xvi. In xv the duct narrows, and continues forward, with about half the thickness it possesses in the above posterior somites. The thickening is due to an increase of a circular muscular layer (figs. 7, 11, 12, 13, 36, 37). The rosettes are in x, xi, as usual.

Prostates. The usual two pairs are in xvii and xix. The lower part is long, slender and muscular, while the upper thicker part is glandular. This glandular part consists of only one layer of cells, covered by a thin epithelium. The glandular cells are of different length, as shown in fig. 32. The muscular part consists mainly of a thick layer of circular muscles (fig. 36), lined by a very thin layer of interior epithelial cells (fig. 38).

Penial setæ. A sac with two penial setæ open jointly with each prostate. At least one of the setæ is sculptured as shown in the figures 31 and 33, with a number of bristles, 12 or more. The smaller seta was broken in all the specimens, and I could not ascertain if it was sculptured or not.

Nephridia. *Benhamia nana* belongs to a group in which the nephridia are arranged in three rows on either side of the median line. There is not a diffuse nephridic condition, but each nephridium is well developed, and upon the same principle as the mega-nephridia of Acanthodrilus. Nephridia *a. b.* are ventral and in front of setæ 3 and 4, while the other nephridium *c.*, is lateral and partly dorsal. The posterior nephridial ducts, from xvii to xviii, are superposed each on a large oval sac of cœlomic cells, while those in front of the male-pore are not furnished with any cœlomic mantle. Of the anterior nephridia those in the genital somites are somewhat smaller than those in the vicinity of the pharynx, the increase in size forward being gradual. Blood capillaries are found in great numbers on all the nephridia, but

especially so on the posterior ones. The general structure of the nephridial canals and their windings resembles those of fully developed mega-nephridia (figs. 39, 40, 41), but the smallness of these organs prevented me from definitely ascertaining the relative size and structure of all the canals. The canal leading to the outlet duct is strongly ciliated. Fig. 41, which represents the inner part of one of the anterior nephridia is held somewhat diagrammatic, as the respective thicknesses of the canals could not be properly delineated. I believe the most anterior nephridia are found in iii, in which somite they are very large, crowding each other.

Benhamia palmicola n. subsp.

Figs. 43–55.

Habitat. Miraflores, in the Cape Region of Baja California, some 40 miles north of San José del Cabo; also around Tepic, territory of Tepic, on the Pacific Coast of Mexico. The altitude of Miraflores is about 1,000 feet, while that of the City of Tepic is about 4,000. Probably the species does not descend to the hot lowlands of the coast belt, at least no specimens have been found either at San José del Cabo or at San Blas.

Color. The specimens are pink flesh, much less opaque than *B. nana*, no pigment cells.

General Remarks. For the present I arrange this as a subspecies under *B. Bolavi*, from which it differs in several points of considerable importance. These are the different form of spermathecæ, the situation of the first dorsal pore, the different sculpture of the largest penial seta, the location of the gizzard, the number of sperm-sacs, etc.

EXTERIOR CHARACTERS.

Size 50 to 60 mm.

Somites 110.

Clitellum incomplete in all somites xiii–xx.

Dorsal pores, most anterior one between iv–v.

Spermathecal pores in line with setæ 1 and 2, between vii/viii and viii/ix.

Oviducal pore. One central median oviducal pore in xiv.

Penial setæ, two in each sac. The longer seta has apex curved and furnished with four blunt, bristle-like crenulations. The smaller seta has the point slightly forked, one prong being longer, and a thin membrane extended between the two forks.

Common setæ. About equal distance between the dorsal and ventral couples as between the ventral couples.

INTERNAL CHARACTERS.

Buccal cavity with a dorsal pocket of sense organs and glandular cells.

Pharynx not situated far forward.

Gizzards both apparently in viii.

Calciferous diverticula, 3 pairs in xv, xvi and xviii.

Septal glands, small in ix and x.

Typhlosole small.

Sperm-sacs in xi and xii.

Spermducts not thickened in the somites near the pores.

Prostates are larger than in *B. nana*, but mostly confined to one somite each.

Spermathecæ in vii–viii and viii–ix. The two divisions are of equal size, and globular; small tubercular diverticle pointing forwards.

Nephridia in three distinct rows on either side of the median line. Nephridium *a* nearest the ventral ganglion consists of two unequal parts, the most ventral of which is the smallest. These two parts together are much larger than either of the other two nephridia. The dorsal nephridia are far apart.

DETAILED DESCRIPTION.

Body-wall and sense organs. We find the same zone of sense organs in the body-walls as in *B. nana*. In *B. palmicola* this zone is found in all the somites, while in *B. nana* I found none in somite i.

The sense-organ zone with pellucid cubic cells is in this species larger than in *B. nana*, and stands out most prominently on the upper side of the buccal cavity.

Septal glands. As has already been stated small septal glands are found in somites ix and x or posterior to the gizzard. These glandular masses are quite small, are situated in the anterior part of the somite, close to the intestine, but hardly projecting above the latter. I cannot find that they are in anyway connected with the pharyngeal system of glands.

Intestine, etc. The portion of the pharynx is not far forward. The region of its epithelial columnar cells is thick and the discharge chambers of the pharyngeal glands are tubular, instead of globular as in *B. nana*. The pharyngeal glandular mass is less lobed than in *B. nana*.

The region between somite i and pharynx is much longer in *B. palmicola* than in *nana*. The specimen sectioned longitudinally showed the two gizzards as both situated in viii, and there was no septum separating them. If this character is constant is undecided as I did not wish to sacrifice another specimen. The tubular intestine is long and cylindrical and furnished with the regular three pairs of calciferous diverticula in somites xv, xvi, xvii. No lime crystals in the posterior pair. The sacculated intestine commences in xviii or xix. The typhlosole is smaller than in *B. nana*, but owing to sand I could not definitely ascertain its location.

Spermathecæ. The four spermathecæ are of the same form and size. The contraction at the center is deep, dividing the organ in two equal, globular sacs, each sac being confined to one somite; that is, the apical part is situated entirely in the somite posterior to the pore. The basal part carries a short narrow cylindrical and tubular diverticulum pointing forwards. The equality in size and the globular form of the two parts of the spermatheca appears very constant and characteristic of the species.

Sperm-sacs are sac-like, not racemose. They are found in xi and xii, while in *B. nana* they are placed in x and xi.

Spermducts are considerably thickened, but the lower part is not any thicker than the upper part, as in *B. nana*.

Gonads are affixed high up on the septum and not at the junction with septum and body-wall.

Prostates. These bodies are larger than in *B. nana*, but nevertheless generally confined to one somite each. The penial setæ are, as usual, of unequal size. The larger seta is furnished with four notches, the smaller is spoon-like and forked at the apex.

Nephridia. These organs are arranged in three distinct rows on either side of the median line, but the nephridia in each somite are of unequal size. The nephridium nearest the ventral ganglion or nephridium *a* consists of two, more or less, separate parts, evidently a tendency to diffusion or an imperfect centralization. The most ventral part is the smallest and the most distal the largest. The ducts run continuously between these parts, but the cœlomic cells are grouped in such a way that the bridges between the two parts are quite narrow. The nephrostome of nephridium *a* was always plain and readily seen, but I never succeeded in finding the nephrostomes of *b* and *c*. Still, these nephridia appear perfectly formed on the meganephric principle, and I could never see any connection by canals between *a* and *b*, and *b* and *c*, though sometimes the cœlomic cell masses extended more or less continuously over and between the respective nephridia *a*, *b* and *c*.

Nephridia *a* open in front of setæ 1 and 2, while in *B. nana* they open in front of 3 and 4. The most anterior nephridium possessing a cœlomic covering I found in xxi. Through the courtesy of Dr. Michaelsen, I have received specimens of *B. Bolavi* for comparison. The nephridium of *B. palmicola* resemble that of *B. Bolavi*, but is much larger, and the respective nephridia cover each other slightly, while in the two specimens of *B. Bolavi* which I dissected the respective nephridia were separated by considerable distance; the latter nephridia are also smaller. I had at first intended to assign these species of Benhamia possessing several nephridia of a perfect form under a separate subgenus, when my attention was called to the fact, by Dr. Michaelsen, that *B. Stuhlmanni* sometimes possessed a similar arrangement of nephridia as those in *B. Bolavi*, etc. As the nephridia of *B. Stuhlmanni* are generally plectonephric or diffuse, it became at once evident that this distinction could not be used as a generic character of value, and that it really is impossible to draw any distinct line between a plectonephric and a micronephric condition. It is, however, entirely incorrect to characterize these nephridia as a mass of tubules, etc., as wherever they are separated one from the other, as in *Bolavi*, *palmicola*, *nana*, *rugosa* and probably great many other species, each micronephridium is perfect in itself, and built on the same general principle as the meganephridia of the other terricolæ. I would therefore propose to make a distinction between plectonephidia, or really diffuse nephridia, and micronephridia, or nephridia of small size, but perfect, or built on the meganephric plan. Such a distinction may be useful in descriptions, even if they are not morphologically distinct.

Benhamia papillata n. sp.

Figs. 43 A, B, C, D, E; 52.

Habitat. Tepic, Territory of Tepic, 4000 feet; Mexico.

I am unable, on account of want of time, to add any detailed description to the short definition of this species given above. When I described *Benhamia palmicola* I possessed only a single specimen of *B. papillata*, and I supposed that the differences in the structure of some of the organs, as well as the presence of the prostate papillæ, were due exclusively to individual variation. But while this paper was being printed I became possessed of about twenty specimens from the same locality, all of which resemble each other in all the points referred to in the description, and I therefore do not hesitate now to assign to them a specific name, especially as I find that this species is much more distinct than I at first suspected. While it in many respects resembles *B. Bolavi*, it differs in other points which must be considered of specific importance. *B. papillata* differs thus from *B. Bolavi* in possessing four exterior tubercles, one for each prostate pore. The smaller penial seta in *B. Bolavi* is flat and somewhat forked, while in *B. papillata* the smallar seta is furnished with a sigmoid tip of exceeding thinnesss. The clitellum in *B. Bolavi* and *B. palmicola* is incomplete, but in *B. papillata* it is complete even on the ventral side, showing several rows of glandular cells, but the width of the layer of clitellar cells is much narrower in the central part. Clitellum is ventrally complete only in somites xiv, xv and xvi.

The following are the other points of interest as regards the character of this species: It is larger than *B. palmicola*. The four papillæ, each one of which carries a prostate pore, are very distinct and prominent, and they stand close together in the sunken genital pit of the clitellum. The median central papilla, on which open the ovipores, is elevated and oval. The two ovipores are situated in the center of the papilla, but entirely separate. They are in the very center of the somite and in a line drawn between setæ 1 and 1. In *B. palmicola* the ovipores join, and the common pore is situated somewhat in front of a line drawn between setæ 1 and 1. Longitudinal section of a specimen shows that the septum separating somites xiii/xiv is very much cupped, and the oviducal funnel is situated exactly above the central papilla in xiv and dips down straight to the ovipore. The anterior septæ are hardly thicker than the posterior ones, but they are all very much cupped. Sacculated intestine commences in xix. There is a strong superior typhlosole in xx to xiv. Of the three pairs of calciferous diverticula the anterior one in xv is very much, or about four times, smaller than each of the posterior ones. The glandular part of the prostate is folded and quite thick, but confined to one somite.

Penial setæ. The penial setæ are the most distinct character of this species, besides the tubercles of the prostate pores. In general shape the two setæ are much more slender than those of *B. palmicola*, and several times narrower at the apex. They are so thin that it required an oil-im. 1/12 to show their structure sufficiently to enable me to sketch it. The larger seta is slightly curved, gradually tapering from the root to the apex. The apex is much less curved than that of *B. Bolavi* or *B. palmicola*, and furnished with seven or eight shallow but still distinct notches. But the smaller

seta differs entirely from that of the *B. Bolavi* group. Instead of being more or less distinctly forked and wider at the apex, as in those species, it is drawn out to an exceedingly thin hair-like point, which is sigmoid (fig. 43 *e*). In shape the seta is almost straight, with the two ends slightly curving.

The *papillæ* of the genital region are most characteristic. Each papilla forms the exterior apex of a prostate. With a low power lens these papillæ appear round, but under a higher power they appear rosette-like, and consist of two or three divisions, one on top of the other. The ventral part of segments xvii, xviii and xix, carrying the genital pores, is much contracted, and the papillæ appear as in a bunch. The distance between the male or spermaducal pore and the prostate papilla is just about the same as the base of the papilla.

In a section the structure of the oviducal median papilla appears to greatly resemble that of the tubercula pubertatis of Sparganophilus. I find there the same relatively large number of tall, narrow cells, radiating from the ovipore, but I cannot discern any sense cells.

The spermathecæ differ in shape from those of *B. palmicola*. The apical sac is not globular, but pointed and narrow, as represented in fig. 52 G and H.

The nephridia also differ some from those of *B. palmicola*. In this species the inner nephridium, or *a*, consists of two parts, each one with a cœlomic mantle separate from the other, but in *B. papillata* nephridium *a* consists of three distinct parts, each one with a cœlomic mantle. This, of course, refers only to the posterior nephridia; the anterior ones are not covered by cœlomic mantle.

Sperm-sacs in x and xi, not racemose. In other respects, as far as I can judge by a hasty examination, this form resembles *B. palmicola*.

Benhamia rugosa n. sp.

Figs. 56–63.

Habitat. Native habitat unknown. The eight specimens in my possession were found in the orchid house in the Golden Gate Park of San Francisco, California, under pots. Two were adult, two imperfectly developed, the others immature. July, 1895.

Color reddish flesh.

EXTERIOR CHARACTERS.

Size, 30 mm. by $1\frac{1}{2}$ m.

Segments, 118. Cephalic lobe very long, pointed.

Clitellum incomplete.

Dorsal pore, most anterior v–vi.

Oviducal pore, one single in the median line in xiv.

Prostate pores, the anterior ones elevated on tubercles.

Penial setæ. Largest seta with five notches, smallest seta forked with prongs of equal size.

Common setæ. All ventral in four couples; the inner setæ are present in xviii.

INTERIOR CHARACTERS.

Gizzards, two in vii and viii.

Calciferous diverticula. Three pairs in xv, xvi and xvii.

Sacculated intestine commences in xviii.

Typhlosole present.

Prostates slender, confined each to one somite.

Spermathecæ. The apical part a trifle smaller than the basal. Both parts much flattened. A very small diverticulum pointing forwards.

Nephridia in four rows on either side of the median line. The posterior nephridia with cœlomic glandular mantle. Nephridia in each somite of about equal size. Nephridia *d* and *d* about equidistant as *a* and *a*. The most ventral part of nephridium *a* not covered by the mantle. The clitellar nephridia larger than those anterior to clitellum.

DETAILED DESCRIPTION.

Size. The specimens had been slowly killed and extended before hardening. All the specimens were curved backwards, thus with the dorsal line on the inner margin of the crescent, causing the male pores to be situated at the greatest bend on the outer margin of the crescent. Most terricolæ curve the opposite way.

Shape of segments. The first ten somites are very nearly of the same diameter in the direction from head to tail. Somites xi and xii are slightly narrower. The clitellum which comprises somites xiii to xx shows plainly the intersegmental grooves. The posterior somites are of a somewhat shorter diameter than xi and xii. All the anterior somites including the most posterior ones of the clitellum are sculptured by longitudinal furrows running in the diameter from head to tail. This corrugation is seen all around the body, and gives the anterior part of the worm a very marked appearance. The posterior somites show a fainter corrugation. All somites are 3-ringed, except those of the clitellum.

Prostomium is long and pointed and slightly curved upwards (figs. 57 and 58) and is a trifle longer than somite ii. In all the specimens but one, somite i, was nearly entirely retracted in the buccal cavity, and when viewed from the exterior only a short portion of its dorsal part could be seen (fig. 58) and the prostomium appeared as if projecting from somite ii. One specimen had somite i extended as figured in fig. 59. Dr. Michaelsen has remarked a somewhat similar retraction of somite i in *B. kafuruensis*. Spermathecal pores as usual, vii–viii and viii–ix.

Clitellum is narrower than the surrounding somites. It is strongly corrugated, especially at the anterior and posterior margins. The prostate pores are, as usual, in xvii and xix. The exterior part of the genital region is very characteristic. In young specimens the two prostate pores are connected by a deep furrow in the center of which is seen the slight depression for the male pore. In the two fully adult specimens, however, the two anterior prostate pores were each situated on a very large globular papilla, surrounded by a deep fossa; while no such papilla and fossa characterized the posterior pair of prostate pores. In fact, these posterior pores

were not visible from the exterior and could only be ascertained by dissection and transparent light. Viewed from the exterior the clitellum appears incomplete.

Penial setæ. The longer seta is hooked at the apex and furnished with five notches on the inner side, very much as in *B. Bolavi.* The shorter seta is less curved and about $\frac{3}{4}$ as long as the larger setæ. It is not hooked and the free apex is slightly forked, each prong being of the same length. There is no flare or wing between the two prongs (figs. 60, 61 and 62).

Oviducts. Both open together in a central pore in the median line in xiv, very close to the groove between xiii–xiv. In the largest of the two adult specimens the ovipore was situated abnormally between xv and xvi.

Intestine and *glands.* A strong supra-pharyngeal gland as usual. Gizzard in vii and viii, separated by a thin wall, as in other species. Tubular intestine extends from gizzard to xvii, and is in xv, xvi and xvii furnished with the three pairs of calciferous diverticula, of which the two anterior ones are of different construction histologically just as in other species. The sacculated intestine commences in xviii. There is a typhlosole.

Spermathecæ. As usual, in vii and viii. Those in vii were slightly smaller, and entirely confined to their somite, while those in viii projected their distal part through the septum into ix. The distal part is only a little smaller than the other part. The spermatheca is much flattened. Seen from below it appears as in fig. 52 *m*, while seen from the side it looks as in fig. 52 *n*. The lower part is furnished with a very small diverticulum, pointing forwards. The duct leading to the pore is very short, almost not set off from the lower sac.

Oviducts are slender, tubular, with a small and narrow funnel.

Nephridia. Those posterior to xix are furnished with a cœlomic cell mantle of oval form, even and regular, and of the same size in the various nephridia. Posterior to xix we find four rows of nephridia on each side of the median line, the rows being regular and parallel. The most ventral nephridium or *a* is situated between the setæ couples 1 and 2 and 3 and 4. The other nephridia *b*, *c* and *d* are dorsal and lateral. The two dorsal nephridia *d* and *d* are about as equidistant as nephridia *a* and *a*, and much closer together than the dorsal nephridia of *B. nana*, *palmicola* and *Bolavi*, the three other species which I have examined. The more ventral part comprising the outlet duct, etc., of nephridium *a* is longer than the corresponding parts of the other nephridia, and not covered by the cœlomic mantle. The clitellar nephridia are larger and their ducts thicker than the other anterior nephridia. The nephridia anterior to clitellum are very small, except those in somites iv and v, where, as usual, the nephridial ducts are long. Each nephridium appears perfect, and built on the meganephric plan (fig. 63).

Benhamia rugosa is readily recognized and characterized by the large papillæ on which open the two anterior prostate pores, by the four rows of nephridia, by the forked smaller penial setæ, by the corrugation of the anterior somites, inclusive of clitellum, by the pointed prostomium, by the flattened spermathecæ.

Since this was written Rosa has described a new American Benhamia from

Paraguay, viz.: *B. octonephra*, which appears to resemble my *B. rugosa* in several points, especially in having four rows of nephridia on either side of the ventral median line, or eight parallel rows in all. But it also differs in several others, sufficiently to be arranged under separate species. *B. octonephra* has about 90 somites, *B. rugosa* about 118. *B. rugosa* possess penial setæ, which, as far as I can judge from Rosa's description are different from those of *B. octonephra*.

Unfortunately, the characteristics of Benhamia species must be founded on most minute characters, which cannot always be expressed in words, as long as so comparatively few species are known. Too few of these characters have been figured, and many have been entirely overlooked. The penial setæ, which are of the utmost importance as species characters, should be in all instances figured. They vary much less than do the spermathecæ, the shape of which is only approximately constant.

ACANTHODRILUS Perrier.

Out of thirty-five species of this genus, which have been described to date and recognized by Beddard, none have been found as far north as Central America or Mexico. The two new additions to the genus which I am able to describe below will therefore prove of considerable interest on account of their habitat so far north, while one of the species shows a combination of characters rarely met with in this genus.

DEFINITIONS OF SPECIES.

Acanthodrilus tamajusi n. sp.

DEFINITION. *Length 15 cm., width 1 cm. in thickest part in front of clitellum; number of somites about 218. Clitellum xiii to xx. First dorsal pore posterior to clitellum. Penial setæ ornamented, one seta only in each sac. Common setæ paired. Prostate pores each on a round papilla. Gizzard in v. Calciferous diverticula 3 pairs in vii, viii and ix. Saculated intestine commences in xiv. Typhlosole present. Spermatheca large sac-like, with a few small warty diverticula. Sperm-sacs not racemose, in ix, x, xi, xii. Prostates four, much folded, opening with penial setæ. Nephridia large, meganephridia, not alternate. Color reddish, partly pigmented. Habitat, Guatemala, lowlands.*

Acanthodrilus Vasliti n. sp.

DEFINITION. *Length 6 cm. by 2 mm. in the region of somite viii; number of somites 92. Prostomium distinct, divides somite 1 about* $\frac{1}{2}$. *Clitellum unknown. First dorsal pore vii/viii; first large dorsal pore ix/x. Penial setæ absent; common seta paired, 1 and 2 not present in xvii and xix. Prostate pores not on papilla; each pore a duplex one. Ovipores in front of setæ 1 and 2. Spermathecal pores in front of setæ 1 and 2, and between somites vii–viii, viii–ix. Spermiducal pores in xviii in line with setæ 1 and 2. Septa v to xii slightly thickened. Gizzard in v. Saculated intestine in xv. No calciferous diverticula. Peritoneum covered with a single layer of very large glandular cells. Very large suprapharyngeal gland, and a very small subpharyngeal gland. Spermatheca long tubular in viii and ix, no diverticula. Prostates 8 in*

number, 2 and 2 opening close together in the prostate pore. Typhlosole. Nephridia large, meganephridia, not alternate, opening in front of setæ 3 and 4. Color milky white, no pigment. Habitat, Tepic, Mexico, 4000 feet altitude.

Acanthodrilus tamajusi n. sp.

Figs. 87–96.

Habitat. Of this species I possess one adult and half a dozen young specimens, principally from Tamaju on the rio Polochic in Guatemala. The largest individual measures about 150 mm., but even this one did not have the clitellum perfectly developed, but was otherwise seemingly mature. One of the smaller specimens measuring only 70 mm. in length possessed a more perfect clitellum than the larger specimen. These specimens were found by myself several years ago in June and July on top of the ground after rain. It is probably a common species in tropical Guatemala. On account of imperfect preservation of the specimens, some histological details are wanting.

Color. Deep violet-brown and iridescent when alive. Skin pigmented strongly on the tail, slightly on anterior part, but only on the upper side in the two mature specimens. A large immature specimen possessed no pigment, and was of a grayish color, but there may be some doubt as to its belonging to this species.

Size. Largest specimen 15 cm. by about 1 cm. in front of clitellum. The specimen had not been extended and killed before being placed in alcohol and must therefore have been considerably longer.

Number of *somites* 218 about, those in front of clitellum much larger than those posterior to it.

First dorsal pore in the pigmented specimens only posterior to clitellum. In the unpigmented between vii and xiii.

Prostomium doubtful (injured), but appears to incompletely or not at all divide somite i.

Clitellum complete, xiii to $\frac{1}{2}$xx.

Penial setæ. A sac with one penial seta at each prostate. This seta has numerous short rows of teeth, decreasing in number towards the apex. The seta is quite short, blunt at one end and broad, tapering gradually toward the apex which is slightly recurved. The whole seta is irregularly sickle-shaped. The teeth are on the concave side. One seta possessed four notches with short teeth also on the convex side posterior to the other, or about where the thickest part begins (figs. 93 A, B, C).

Common setæ strictly paired on ventral side of body. The distances between the couples about the same. The ventral couples of setæ are present near to the spermiducal or male pores. They are the ordinary form but slightly larger than the common setæ.

Oviducal pores in xiv situated somewhat nearer the median line than to the inner couples of setæ, and the distance between the pores is a trifle more than the distance between setæ 1 and 2 in the same somite.

Prostate pores situated each on a small papilla.

Gizzard is in v.

Calciferous diverticula, three pairs, one each in vii, viii and ix, all of the same structure.

Sacculated intestine commences in xix and furnished with a typhlosole.

Spermathecæ in viii and ix with a few warty diverticula, one of which is larger and furnished with two swellings. Spermathecal pores in front of setæ 1 and 2. The spermathecæ are large, filling the space between the septa on the ventral side of the body. No spermathecal copulary setæ.

Sperm-sacs sac-like, not racemose, occupying the whole space left in ix–xii.

Prostates much folded, opening with penial setæ; each prostate confined to one somite each, the free distal end pointing backwards, and situated close behind the male pore.

Nephridia, strictly meganephridia, not alternating.

DETAILED DESCRIPTION.

Each prostate pore is situated on a round globular papilla, between which and the male pore runs a copulatory fossa. In xvi and xx there is in each a copulatory ridge, running parallel with the intersegmental grooves and somewhat longer than the space between setæ 2 and 2 (fig. 91). There is a shorter ridge in xviii extending between the male pores.

The *prostomium* and somites i and ii are transversely sulcated, most so somites i and ii. Also somite iii shows this sulcation in a smaller degree. The anterior nine somites are more or less distinctly segmented in three parts, that is, they show a central ridge on which are situated the setæ. The following posterior somites show a segmentation in five parts. In the clitellium the segmentation is clear, as far as regards the intersegmental grooves, but the segmentation of the somites is not very distinct.

The *supra-pharyngeal glands* form a very large body, superposing the pharynx. It is rounded posteriorly, and consists of four larger and five smaller lobes, this when viewed in a longitudinal section just outside the median line (fig. 96).

The *calciferous* diverticula show all the same structure.

The *spermathecæ* are large, globular masses, as seen in figs. 94 and 95, with warty diverticula, one of which is much larger. The spermathecæ overlap each other and are bunched in a solid mass between the septa on the ventral side of the body.

Testes are in two pairs, quite or very small when viewed in sections—in x and xi, in front of the ciliated rosettes, on the posterior face of the anterior septa.

The *ciliated rosettes* or sperm-funnels are in xi and xii, and are very large, crimped and furnished with a wide muscular duct. The funnels in xii lie much higher up than the one in xi, much closer to the intestine. The posterior part of the funnel is very thick, and so is the duct. The ducts join and open as usual in xviii. The rosettes lie free, but are connected by connective tissue with the anterior septa. They thus point backwards.

The *body-wall* is very thick, and the longitudinal muscles are not bipinnately arranged. The septa between v, vi and so on until xi, xii, are much thickened, and thicker than the other, though the one between xi, xii is not as thick as the anterior

ones. The gizzard is connected by several powerful muscular strands with the body-wall in xi.

There is a very large mass of *pepto-nephridial* tubes situated immediately above the posterior part of the pharyngeal gland. Longitudinal sections show the anterior nephridial canals to be greatly folded and very narrow. There are very large masses of free cœlomic cells situated in the somites containing the sperm-sacs and the funnels of the spermducts.

Acanthodrilus Vasliti n. sp.

Figs. 148–154.

General Remarks. This species is one of those abnormal forms which occur in almost every large genus, and whose organization and characteristics are not readily accounted for. It is also the most northern of any Acanthodrilus found so far, though undoubtedly true Acanthodrili will be found much further north. *Acanthodrilus Vasliti* differs from any other Acanthodrilus in possessing eight prostates or spermiducal glands, arranged in four pairs, two and two prostates opening together in each one of the four prostate pores in somites xviii and xx. Also in one other respect does this species show an interesting characteristic. The peritoneum lining the septa and body-wall is covered with enormous glandular cells, very much resembling those forming the nephridial mantle in many species. The duplication of the prostates is also found in *Kerria McDonaldi*, while abnormal development of peritoneal cells remind us of certain cœlomic organs found in Perichæta and some species of Acanthodrilus (Beddard, page 29, Monograph of Oligothæta). Four pairs of prostates have been described by Ude in *Geodrilus singularis*, but details are wanting.

Of the specimens in my possession one was sectioned longitudinally, two were dissected and afterwards sectioned vertically. None of the specimens were fully adult; the various generative organs were developed, but there was no trace of clitellum.

Habitat. Tepic, Territory of Tepic, Mexico, at 4000 feet altitude, in the moist ground immediately under decaying logs, in the shade of a stone-fence, about one mile north of the city. October, 1894, Eisen and Vaslit, col.

Color. Milky white, like an Enchytræus, without trace of pigment.

Size. Length 6 cm. by 2 mm. in the region of somite viii. Slightly tapering towards the tail, the end of which is thickened.

Number of somites 92 in the largest specimen, all of about the same size, except the last few caudal ones, which diminish in width towards the most posterior somite. All are smooth, the anterior ones with a faint trace of trisegmentation.

Dorsal pores. The most anterior one that is distinct is seen between ix–x. Between vii/viii and viii/ix there is respectively a much smaller but still distinct pore. The most anterior pore is thus between vii/viii.

Prostomium is distinct, dividing somite i about $\frac{1}{2}$. The anterior somites are more distinctly set than the others. A long narrow groove begins on the ventral median line between somites xvi and xviii, and extends backwards about 20 to 25

somites, then changes into a narrow keel. This in the largest specimen, all having been slowly killed and straightened out.

Clitellum unknown, all specimens being immature.

Genital pores. Two pairs of *spermathecal pores* between ix–viii and viii–vii, in front of the respective septa, the spermathecæ thus being in ix and viii. The pores are in line with setæ 1 and 2, but are not prominent. *Oviducal pores* are in front of setæ 1 and 2 between xii/xiv.

Prostate pores in two pairs in the center of somites xvii and xix, in line with setæ 1 and 2. But each pore is really a duplex of two joint pores, which are only separated at the very epidermis by a thin wall. Thus the two prostates of each couple run parallel through the body-wall, each one opening separately, but the pores being so closely joined that they appear almost as one. No setæ of any kind near these pores (figs. 151 and 152).

Spermiducal pores are seen in line with setæ 1 and 2, close posterior to the setæ, only visible by strong transmitted light. The genital region in my immature specimens did not show any particular structure with papillæ, etc. The median fossa already referred to causes these pores to be situated on a slight ridge, which was not marked off laterally. Close to each prostate pore on their ventral side is a small tubercula pubertatis, only visible in sections.

Penial setæ absent.

Common setæ. Strictly paired ventral and lateral; 3 and 4 being situated slightly ventral, below the horizontal line. Setæ 1 and 2 are missing in somites xvii and xix. In xviii the ventral setæ 1 and 2 are present, but do not differ from the other setæ, which are all plain and sigmoid.

Nephropores in front of setæ 3 and 4.

INTERNAL CHARACTERS.

Body-wall offers no prominent characteristics, except that the peritoneal layer is enormously developed in all somites posterior to xiii. Peritoneum is strongly vascular, but in addition to the usual small peritoneal cells we meet with a thick layer consisting of a single row of tall peritoneal cells of varying but fairly even height.

Peritoneal cells are in places as high as the other layers of the body-wall combined, while in other places they are shorter. Similar peritoneal cells cover also the septa, principally those posterior to xiii. The center of the septa bear as a rule the tallest cells (figs. 149 and 153). These cells show a round nucleus and a granulation which resembles that of chloragogen cells, but which does not stain deeply as does the one of the latter cells.

The hearts in x, xi and xii, as well as the septal glands in vii and viii, are also surrounded by similar cells. The dorsal blood vessel again is covered by regular chloragogen cells.

Septa. Those separating respectively somites v to xii are slightly thickened and very strongly cupped, but not covered by any peritoneal cells. The septa separating xii to xiv are less cupped, not thickened, but all covered by a few peritoneal

cells. The septa posterior to somite xiv again are not much cupped, but each one is lined on each side by a single layer of very thick tall peritoneal cells (fig. 153).

Alimentary canal. *Pharynx* is furnished with a large upper chamber and is apparently only developed superiorly, although it possesses a small subpharyngeal gland close to the ventral nerve cord.

Œsophagus rises diagonally upwards and joins the single *gizzard* situated in v. The *tubular-intestine* extends to xiv. The *sacculated-intestine* commences in xv. There is a typhlosole in the dorsal wall of the intestine in xvi to xix. The typhlosole presents a network of fibres resembling in a general way the structure of a sponge. This typhlosole does, however, not descend into the canal, but partakes more of the nature of a wide continuous blood-sinus.

Salivary glands. The suprapharyngeal glands form a mass with five distinct lobes, of which the posterior one, as usual, is the largest and the anterior one the smallest (fig. 149). There is also a subpharyngeal gland very low but rather long (fig. 149). A thin but wide septal gland is found in vi, posterior to the gizzard, while smaller septal glands, which are principally developed ventrally are found in vii and viii.

Spermathecæ consist of two pairs of long and narrow organs in viii and ix opening in the intersegmental grooves between vi and viii and viii and ix. In my specimens they were probably rather undeveloped and did not show any trace of diverticula either externally or in the wall.

Testes are in x and xi and *ovaries* in xiii. The *oviduct* opens between the setæ and septum. *Spermiducal funnels* or rosettes are very small, thick and compact, and situated in x and xi. The *spermducts* run separately backwards between the longitudinal layer and peritoneum and open jointly on the center of xviii as usual.

Prostates are in four pairs as has been already stated, two and two opening in each pore in line with setæ 1 and 2, these setæ, however, not being present in these somites (fig. 150). The prostates showed no glandular part, the whole being muscular (fig. 154). They were very thin, tubular, the two prostates in each twin couple running entirely parallel and close together along the septa, as far as the line of setæ 3 and 4. A large part of this distance the muscular part is surrounded by regular peritoneal cells, not by the large glandular ones. Each prostate remains separate from the other and even their external pores, though situated close to each other, are not strictly joined, though they are surrounded by a common thicker lip (figs. 150 and 151). I have already referred to the duplication of prostates in one species of Kerria, otherwise it has not been found with certainty in Acanthodrilidæ. Some of the earliest described Acanthodrilides were, however, supposed to have a prostate and spermducts open jointly, and it does not seem unreasonable to suppose that in some case at least a duplicate prostate existed, and one was mistaken for a spermduct. This would be quite easily done in specimens poorly preserved, especially if the prostates should be entirely muscular as in *Acanthodrilus Vasliti*, in which species they are also very narrow and thin and not really wider than the spermducts of many forms. Ude, in describing *Geodrilus singularis* from Danville, Illinois, mentions as one of the

generic characteristics four pairs of prostate glands, but does not describe nor figure these in detail. The only way I can understand the presence of four pairs of prostates opening into four pores, is that two and two prostates open together. But on the following page (70) we are told that there are two pairs of prostates in segments 18 to 22, which open in segments 17 and 19. The figure shows us four prostate pores. If the first statement is not a misprint, we would in *Geodrilus singularis* have an analogy similar to what we find in *Acanthodrilus Vasliti*. But Beddard states in his large monograph on Oligochæta that *Geodrilus singularis* is probably identical with *Diplocardia communis*. This could, of course, not be the case if the prostates were duplicated in the former.

Tubercula pubertatis. Although no large and prominent elevation in the genital region is found, I have, however, satisfied myself that a tubercula pubertatis is really present even in my undeveloped specimens. Adjoining the prostate pore is a small tubercle, consisting of some tall supporting cells surrounding a bundle of sense cells, the latter characterized by the usual long, oval nuclei. These nuclei are situated much deeper than they are in the sense cells of the epidermis or in the buccal cavity, and they are also narrower than those. Otherwise this organ shows a very great resemblance to those in Benhamia, except for the absence of the glandular refractive cells. At the base of the sense cells in the tubercle I find numerous smaller round nuclei, the relationship of which my sections do not fully explain. Numerous nerve fibrils are seen to connect with the sense cells. Although no clear glandular cells are seen around the sense-organ in the tubercle, it may be possible that some may develop later at the same time as the clitellar cells, none of my specimens possessing any.

Vascular system. The last heart is in xi. The dorsal vessel is single; no subneural vessel. A large blood sinus in xvi to xix inclusive.

Nephridia are strictly paired, opening in front of setæ 3 and 4. Those posterior to somite xiv are surrounded by large peritoneal cells, while those anterior to xv consisted of the usual narrow ducts, free of any cœlomic peritoneal cell mantle. Numerous blood vessels cover the nephridii. The most anterior nephridium is found in iii. No pepto-nephridium. The anterior nephridia gradually diminish in size towards the anterior part of the body.

ALEODRILUS n. gen.

Figs. 66 to 86.

Definition. *Acanthodrilidæ. Paired meganephridia, not alternating. Prostate pores, two pairs; one pair in xx and one pair in xxii. Spermiducal pair of pores in xxi. No calciferous glands; no penial setæ. Two pairs of spermathecæ in viii and ix. Clitellum xiii–xx. Two gizzards.*

General remarks. I possess only one single specimen of this interesting oligochæta, collected at Ensenada de Todos Santos in the northern part of Baja California. My time for searching was very limited and the season unfavorable, and this will account for the want of specimens. The single specimen was found in the dry

bed of the river south of town at a water-hole in the otherwise dry creek bottom sand. It occurred here with Deltania and Limnodrilus. The sand was merely moist on account of overlying rubbish and sacks. The species is undoubtedly a native one and the only Acanthodrilid found on the coast so far north in the open ground, and and on this account even of geographical interest. The intestine of the worm was gorged with the coarse white sand of the river bed. The anterior part of the worm was cut lengthwise, one-half dissected and the other half sectioned crosswise. The want of specimens made a full investigation impossible, though I believe none of the important points remains in doubt. I have no reason to believe the species is scarce, though probably it is sharing the fate with all native worms, that of being displaced by European importations. The species is dedicated to Professor W. S. Keyes, my companion in many travels in tropical Mexico.

Affinities. It is interesting to note that Aleodrilus shows considerable affinity to the only other North American genus of this family, viz.: Diplocardia. It resembled this genus by having two gizzards, no calciferous glands, meganephridia, no sacs with penial setæ. It resembles Benhamia in having two gizzards, etc., but it differs from these two, as well as from all other Acanthodrilidæ, by the far backward position of the prostate and spermiducal pores, these being in xx, xxi and xxii respectively, while all other genera of this family have these respective pores in xvii, xviii and xix. The genital male pores are thus in Aleodrilus pushed three somites further back. Considering these and some minor characters I believe I am justified in placing this worm in a new genus.

Aleodrilus Keyesi n. sp.

Definition. *Length 7 cm., by 5 mm. wide; number of somites 80. First dorsal pore viii–ix. Clitellum complete in anterior, incomplete in the posterior somites,* $\frac{1}{2}$*xiii–*$\frac{1}{2}$*xx. No penial sacs and setæ. Common setæ paired, those of the inner couple closer than those of the outer couple. Spermathecal pores between vii/viii and viii/ix. Gizzards in v and vi. No calciferous glands. Nephridia not covered by a cœlomic mantle. Nephropores outside of setæ 4. Hearts in x, xi, xii. Sperm-sacs racemose in x, xi, xii. Testes in x, xi. Color pale flesh, no pigment. Habitat, Northern Baja California, at Ensenada de Todos Santos.*

EXTERNAL CHARACTERS.

Color is very pale, mottled and marbled, showing clearly the intestines and blood vessels. When collected this worm resembled in delicacy of color and transparency *Deltania elegans* and I supposed it to be this species. *Spermathecal pores* are separate in front of setæ 1 and 2 between vii/viii and viii/ix. *Setæ* are ventral and lateral, 8 in each somite approached in couples. The setæ of the inner couple is closer than those of the outer couple. The distance between the couples is about twice as large as the distance between setæ 1 and 2, and one and one-half as wide as the distance between setæ 3 and 4. No penial setæ in special sacs. All setæ are sigmoid without sculpture. The anterior five somites are two-ringed, that is with a single groove in the equatorial region, while all the following somites are four-ringed, or

with two parallel grooves in the equatorial region. The posterior somites are very wide and four-ringed, but the segmentation is irregular.

Ovipore a little interior to seta 1; nephropores outside of seta 4.

INTERIOR CHARACTERS.

Body-wall. There is a special zone of sense organs in the anterior somites as in Benhamia, but they are more scattered than in this genus. The longitudinal muscles run irregularly, with no trace of bipinnate arrangement. The strands are rather narrow. The longitudinal layer is very narrow, especially in the clitellum. The transverse layer consists of only 3 to 4 strands. The hypodermis offers nothing of special interest.

The longitudinal layer in the clitellum is greatly diminished in thickness, most so in the lateral and dorsal region of the clitellum. Anteriorly in somites ii and iii, the longitudinal strands leave the body-wall and spread out fan-shaped to the inner wall of the prostomium, forming retractor muscles for the upper and lower lips.

Arciform muscles. In somites xx, xxi and xxii we find on each side of the ventral nerve-chord several oblique or aciform muscles, running from the region of the copulatory grooves to the region above the lateral setæ, thus serving to depress and relax the two grooves. These muscles are confined to a single row, and do not show a complex arrangement, as is so frequently shown in oligochæta.

Septa. The septa between somites vii and xiv are much thicker than the others, especially thickened are those separating somites from vii to x. Those between x and xiii are less thick than the anterior ones. The thickest septa, vii/viii, viii/ix, ix/x, are much thicker than the body-wall. The most anterior thick septum is the one which posteriorly bounds the gizzard (fig. 74).

The septum next anterior to this, the one which separates the two gizzards, presents the peculiarity of not being attached to the body-wall, between vi and vii, but it extends forward parallel with the intestine and passes in front of the brain on the upper side, while the ventral side is attached to the œsophagus below the pharynx. It forms thus a sac, as in various species of Benhamia. Anterior to this septum I find no trace of others.

Alimentary canal. The pharynx is well developed and superposed by a very large glandular mass, which consists of about six layers of lobes, attached to muscular strands, as usual. The most posterior mass is the thickest. The discharge pockets of these glands into the pharynx are much thicker than any I have seen in other species, but are otherwise not of any characteristic construction.

Septal glands are situated far back in somites vii to xi. They are of the same nature as those which discharge in the pharynx, but I have good reasons to believe that the glands in this species discharge in the tubular intestine. I have been able to follow the discharge duct as far as to the muscular layers of the intestine, which would hardly have been the case if the ducts had continued forwards into the pharynx, as do those of the forward septal glands in many genera. A peculiarity of these glands is that they are especially developed on the ventral side of the intestine (fig. 75) and

are distinctly paired. On the median line below the intestine the ends of each glandular mass meet and join into one duct, the one I have just referred to. The free ends of the glandular masses are attached by mesenteric tissue to the ventral or subintestinal blood trunk.

A much smaller tubular gland of the same nature runs between the dorsal vessel and the intestine; discharge duct unobserved. A yet smaller gland is seen above the subventral vessel in the same somite as the former; its discharge duct could not be followed.

These glands stain exactly as the common supra-pharyngeal glands and septal glands, but they show no similarity as regards reagents with the chloragogic cells of the intestine and blood vessels, in corresponding places in the somites posterior to xi. The septal glands appear to be of about equal size, a close examination being impossible, from want of sufficient material.

Other glands are found in the epithelial walls of the intestine, arranged in clusters, like the cloves in a garlic. They are scattered about at short intervals among the epithelial cells, and appear of the same nature as those I have described in Argilophilus, but they are not as numerous as in that species. They do not stain freely, but stand out bright and pellucid among the darker staining cells.

Typhlosole not present.

Gizzards are connected by a very thin wall of the same nature as the œsophagus. As far as I can make out the gizzard must be in v and vi, at least the posterior gizzard is bound by the septum separating vi and vii. The circular muscular layer is about 30 strands wide, and is at the widest place about four times thicker than the epithelial layer and cuticle together. The whole width of the gizzard wall is little more than twice that of the body-wall in that somite. The longitudinal muscular layer of the gizzard is only one single strand thick, and the thickness of this strand is less than any one strand of the circular layer of the gizzard. The epithelial layer is comparatively thick, about one-fifth of the whole gizzard. It contains the same peculiar glands as I figured in Benhamia.

Spermathecæ. The absence of diverticula is interesting in as much as most species of related genera possess them. There are, however, some warty elevations. The muscular or basal duct is very long, slender and tubular, several times longer than the upper ovoid sac (fig. 74). The muscular part offers no peculiarities of structure. The spermathecæ occupy each only one somite. They stand upright following close to the anterior surface of the septum.

Testes are greatly lobed and are situated high up on the septum, just as are the ovaries.

Spermducts and ciliated rosettes. The spermducts are separated, but enclosed in a common muscular sheath until somite xxi is reached. Between xx and xvi the two ducts fuse into one lumen, which opens out into the center of somite xxi. The double lumen runs along the circular muscular layer forward until somite xiii/xii, when the respective ducts rise upwards following the septum to the ovary and testes. From here on forward each duct is thicker and muscular, and instead of following the

body-wall passes straight through the cœlomic cavity to the anterior septa, which they pierce immediately at the base of the ovaries and testes (fig. 78). A double lumen is seen only after it passes posteriorly to the ovary. The rosettes are not large, but thick with a wide base; the latter is furnished, where it passes through the septum, with several small sac-like glands, each with a distinct lumen, which I followed through the muscular layer of the spermduct and which I suppose empties into the neck of the rosette (fig. 79). The rosettes are not enclosed in the sperm-sacs.

Sperm-sacs. The three pairs of sperm-sacs are racemose, but not exceedingly so. There are four or five large lobes of globular shape seen in every section suspended from the septum and on the under side of the intestine, though somewhat projecting above it. The two anterior sperm-sacs in x and xi are smaller than the posterior one in xii, the one in x being the smallest of the three pairs. Those in x and xi are suspended from the anterior septum separating x/xi and xi/xii. Of the position of the posterior sperm-sacs I am uncertain, but it appears suspended from the posterior septum, the one separating xii/xiii, as far as I can judge from a cross-section.

Spermatogonia. In the two anterior sperm-sacs the spermatogonia offered nothing peculiar as regards the development of the spermatozoa. There is in each sperm-sac a large central zone of peculiar cells, staining differently. They re situated very close together, and possessed in my preparation rather shrunken nuclei (figs. 63 and 75). This zone exists in all the various sperm-sacs in the anterior as well as in the posterior ones. The development of the spermatozoa in the two anterior pairs appeared entirely normal, the spermatogonia possessing the same form as in other species, the large nuclei standing out freely like beads above the wall. But in the posterior sperm-sacs the spermatogonia, one and all, looked quite differently. They were here of many varying sizes, some small, some enormously large, and the nuclei, instead of standing out from the wall of the spermatogonium, were always bunched in the center, or strung across it as a central band (75). In other spermatogonia the nuclei were arranged as in a ring along the cell walls, but without pushing out. When the nuclei were in the center there appeared always a row of large and small vacuoles along the cell-wall. I find two sizes of nuclei, the smaller being always less in number, and about four times smaller than the large nuclei. When counter-stained with orange, the larger nuclei give quickly up part of their hæmatoxylon, the smaller ones giving it up slowly and not at all. The cytoplasma of the spermatogonia presented a very strong polarity as regards its position, it being always massed towards the cell-wall nearest the central germinative area (fig. 63). A somewhat similar process of developing spermatogonia have been described by Vernon in the sperm cells of Bombyx. The central germinative cell in Bombyx appears to correspond with the central area or cell agglomeration in Aleodrilus, but I have seen no such budding out of the germ cells as figured by Vernon, but this may depend on the insufficient material at my command.

A large number of similar spermatogonia were found in very large numbers in nearly all the anterior somites, either loose in the cœlomic cavity, or in a

peculiar tissue which fills much of the cœlomic cavity. This tissue consists of large, more or less connected cells, very much like the cœlomic glandular cells surrounding so many nephridia. These cell masses are more or less diffuse, and appear not distinctly connected with any of the interior organs of the body. Among these cells are found scattered about large masses of spermatogonia, all in about the same stage of development. There are also numerous small free cœlomic cells, such as found in all earthworms.

Nephridia. There is one pair of mega-nephridia in each somite. The nephridium is very large, projecting above the lateral line of the body. The nephropores—at least some of them—are seen outside of or more dorsal than setæ 4. The nephrostome again is as usually seen very near setæ 1. There are no glandular cœlomic mantles on any of the nephridia. The anterior fold is much wider then the posterior one. The windings are very deep and twisted, and the spur generally sigmoid. The outlet duct, which is tapering towards the pore, is much darker than the other ducts. Its prolongation into the anterior fold forms there the central wider canal, which is also darker than the other two. The canal in the bridge continues forwards and upwards through the anterior fold, and is there the posterior one of the three canals.

Vascular system. The ventral and dorsal longitudinal vessels are both single. There are connecting vessels in somites vii to xii. In x, xi and xii, these vessels are very large, and take the form of so-called hearts. Each heart consists of four or five links, increasing in thickness upwards. Between each two links there is a thick circular valve. Similar valves are seen also in the dorsal vessel at the junction with the hearts. At the base of some of the valves are seen two rows of very large cells, the nuclei of which are about 3 to 4 times larger than the nuclei in the valve cells (fig. 83). All the valves in the hearts point downwards or ventrally. There are no glandular cells in the vessels, such, for instance, as are found in Pontodrilus, etc.

Posterior to the hearts we find long, tubular connecting lateral vessels, between the dorsal and ventral trunks, in the anterior part of each somite. These vessels, one pair in each somite (fig. 86), are of even thickness throughout, but with two short knob-like diverticula, one above the other, about equal distances from each other and from the longitudinal vessels. Both the dorsal vessel, as well as the laterals, are thickly covered with cœlomic chloragogen cells of a yellowish opaque color. These cells do not cover the ventral longitudinal vessel. These lateral vessels contain no valves.

Each valve consists of several circular rings, each containing a number of muscular strands enclosed within a common membrane. In longitudinal sections of the vessel most of the nuclei lie parallel with each other, but the outside ones run as the periphery in a circle. The smaller valves consist each of only one such lobe (fig. 73*a*), while the large ones are composed of several (fig. 73*b*).

SPARGANOPHILUS Benham.

DEFINITION. *Aquatic oligochata. Eight setæ in four couples. Prostomium not marked off from peristomium, but furnished with a superior pit. Few dorsal pores. Clitellum very large, from eight to twelve somites. No penial setæ. Spermathecæ in vii, viii and ix, from two to eight in each somite. Sperm-sacs in xi and xii, racemose. Specmduct always subepidermal. Male pore xviii/ix, or anterior part of xix. Prostates generally present in three or four pairs situated several somites posterior to the spermiducal pores. No gizzards, no calciferous diverticula, no typhlosole. Four pairs of hearts. Two pairs of lateral, longitudinal integumental vessels extending forward from somite xiv, not connecting anteriorly with the gut-wall and median trunks. Nephridia meganephric, commence in somite xii or xiii.*

Principal *species characters* are derived from the position of the setæ; number and shape of spermathecæ in each somite; lobulation of the sperm-sacs; course of the spermducts; shape and position of tubercula pubertatis, whether dorsal or ventral, to the male pore or spermduct; extent of clitellum; presence of a subpharyngeal integumental gland in iii; length of worm and number of somites, etc.

GENERAL REMARKS.

The first species belonging to this genus was described by Benham from the river Thames in England. Later, Frank Smith described another species from North America and it became doubtful, as first suggested by Benham, if the genus was originally an American or European one. The very restricted locality or habitat of the European species would indicate its probable importation from some other country, and when the American species was found it became almost certain that we had to search for the original home of this genus on the American continent. Already when Benham's paper was published I had in my possession specimens of this genus from Guatemala, California and the Central North American States, and there remained no doubt in my mind as to the native habitat of the genus. As it now stands we have seven species sufficiently well defined to be recognized and one more of which no detailed description can be had, but of which we know enough to be able to recognize it should it again be observed. Of these eight species then seven are American and one European, and everything points to the probability that the latter one is a lately imported species to England most likely from this country, as Benham originally supposed.

The species described here below are not of equal value as species as might be naturally inferred. Four of the species are well defined, which principally is due to better preserved and abundant material for study. These species are: *Sparganophilus tamesis, Eiseni, Benhami* and *Smithi*. Two are less well-known, due entirely to want of sufficient well preserved material. These species are *Sparganophilus carneus* and *guatemalensis*, both of which may prove only varities of *Sp. Benhami*. The remaining species *Sparganophilus sonomæ* may prove a variety of *Sparganophilus Smithi*, but just as such all the more interesting.

A point of unusual interest in this genus is the presence of prostates, or, as

Beddard calls them, spermiducal glands. These glands are, in Sparganophilus, situated much further from the male or spermiducal pores than in any other genus, apparently quite independent of the pores. They are also subject to considerable variation, in some species being three, in others four; in one species none. Of the same nature I consider the forward parietal pair of glands in somite iii of *Sparganophilus Eiseni*, and it seems not unlikely that originally this genus possessed many more pairs of spermiducal glands, perhaps one in every somite. This location of the spermiducal glands favors greatly Beddard's view that these glands were originally independent of the spermduct, and according to this view these glands are in Sparganophilus the most primitive of any. There is also much difference as to the development of these glands in the various species. Thus in *Sp. Benhami* the gland consists of two distinct parts and is both glandular and muscular, while in *Sp. Smithi* the muscular part is degenerate or undeveloped, the whole gland being very diminutive. Another point showing the primitive arrangement of the spermiducal glands is the absence of any copulatory setæ, the common setæ in their vicinity being unmodified.

There is no doubt that a large number of species of this genus will soon be found on the American continent, especially as specimens appear numerous and widely distributed. In Guatemala I found them everywhere in springs and lakes, and a hasty examination of live specimens satisfied me that there were among them about three species, characterized by the position of the hearts, whether in viii–xi, ix–xi, or x–xiii. Unfortunately my Guatemala collection was destroyed and only few specimens in poor condition remain.

In this connection I will also call attention to another species of Sparganophilus not described below, but found by me several years ago in the small lake known as Laguna Puerca, situated near the ocean at San Francisco, California, or in the same lake as I now find *Sparganophilus Smithi*. This species which I have since been unable to re-collect, although I have made repeated excursions to the place and dug at the identical spot, offered much of interest and was undoubtedly a different form from any now described below. It was much shorter and thicker, about 5 cm. long by 4 mm. thick, or about half as long and twice as thick as our smallest species now known. The hearts were, according to a fieldnote, situated in vii, viii, ix, x. The longitudinal lateral vessels began in xiv, but most interesting of all, the species possessed five distinct and large eye spots on the first somite and prostomium, an occurrence not recorded in any other of the higher earthworms.

The specimens were very rare—I could only find two or three in an hour; they occurred in the clay soil near the shore at shallow depth.

In connection with this it is most interesting to note that at that time I found no trace of *Sparganophilus Smithi*, which now occurs in the same lake in countless numbers, a worm many times longer and much thinner. It is impossible that I could be mistaken in regard to my former observations. My explanation is this: Formerly the Laguna Puerca was much lower, the bottom soil near the surface was clayey, while now the lake is several feet higher, the bottom soil near the surface is sandy. A

number of vegetable gardens have of late years been established at the headwaters along the creek furnishing the lake, and it is probable that *Sparganophilus Smithi* has been introduced with watercress, etc., from some other locality within the last few, say ten years, while the eye-bearing species may yet be living in the bottom soil.

KEY TO THE SPECIES OF SPARGANOPHILUS.

I. Setæ 3 and 4 ventral; no prostates, spermducts dorsal to tubercula pubertatis.
SPARGANOPHILUS TAMESIS Benham.

II. Setæ 3 and 4 dorsal, prostates present, situated several somites posterior to the male pores.
A. A pair of ventrally situated parietal glands in somite iii. Spermducts and spermiducal pores dorsal to tubercula pubertatis. SPARGANOPHILUS EISENI Smith.
B. No ventral parietal gland in any somite.
x. Spermiducal or male pore ventrally situated to the tubercula pubertatis.
a. 8 spermathecæ in each of somites vii, viii, ix. 2 ditto in vi. SPARGANOPHILUS SMITHI n. sp.
b. 4 spermathecæ in each of somites vii, viii, ix. 2 ditto in vi. SPARGANOPHILUS SONOMÆ n. subsp.
xx. Spermiducal pore dorsally situated to tubercula pubertatis.
c. Spermathecæ trowel-shaped, outline crenulated. SPARGANOPHILUS BENHAMI n. sp.
d. Spermathecæ trowel-like, but outline smooth. SPARGANOPHILUS GUATEMALENSIS n. subsp.
xxx. Spermiducal pore unknown, but probably dorsal to tubercula pubertatis
e. Spermathecæ club-like, apical end globular, smooth. SPARGANOPHILUS CARNEUS n. sp.

Sparganophilus tamesis Benham.

DEFINITION. *Length 7 to 10 cm. Clitellum 1-2 xv–1-2 xxv. Tubercula pubertatis xvii to xxii ventral to spermiducal pore. Setæ 3 and 4 ventral. Spermiducal pore between xviii and xix dorsal to tubercula pubertatis. Sperm-sacs in xi and xii minutely lobulate. Spermathecæ one pair in each of somites vii, viii, ix, ventral. No prostates. Anterior nephridium in xiii. Septal glands in v and vi. No subpharyngeal integumental gland. Blood capilaries on nephridia are numerous. Continuous blood sinus in the sacculated intestine. Hearts in viii, ix, x, xi, not filling the cœlom. Color pinkish with violet iridescence. Habitat, England, Thames.* Description is compiled after Benham's paper only, as I have not seen any specimens.

Sparganophilus Eiseni Smith.

DEFINITION. *Length 18 to 20 cm.; width 26 cm. Clitellum dorsally 1-4 xv–xxv, ventrally 1-2 xiv–xxvi. Tubercula pubertatis 1-2 xvii–1-2 xxii, ventral spermathecal pores. Setæ 3 and 4 dorsal. Spermiducal pore in anterior part of xix, dorsal to tubercula pubertatis. Sperm-sacs minutely lobulate. Spermathecæ, one pair each in vii, viii and ix, all dorsal. Prostates 4 pairs in xxiii–xvi; muscular duct present. Anterior nephridia commence in xiii. Septal glands in iv, v, about the same size, while the one in vi is very small. A subpharyngeal parietal pair of glands present, opening in front of setæ 1 and 2 in somite iii. Blood capillaries on nephridia are many. Continuous blood sinus in sacculated intestine present. Hearts in viii, ix, x, xi small. Color violet flesh. Habitat, Illinois, North America.*

Prof. Frank Smith has kindly sent me for comparison a full set of sections of this species, also several mature specimens in alcohol and formalin. As, however, Prof. Smith writes me that he intends to further work out the details of the anatomy and histology of this species, I have not considered myself at liberty to more than

touch upon a few essential points of importance in further characterizing this species from its other American allies. The species is nearest related to *Sp. Benhami* and its subspecies. The main points of difference and similarity may be found in the comparative table of the species of Sparganophilus. *Sp. Benhami* is a much more slender form than *Sp. Eiseni*, especially as regards the body posterior to clitellum. The ventral side of the genital regions in the two species differ. Thus in *Sp. Benhami* the ventral depressed area between the tubercula pubertatis and the oviducal pores is circular or oval, while in *Sp. Eiseni* it is contracted in the middle, the shape of a sand time-glass. The presence of a small parietal gland in somite iii in *Sp. Eiseni* distinguishes this species from all others known so far. This gland is paired, extends considerably into the cœlomic cavity, is racemose and opens to the exterior in front setæ 1 and 2, and projects its free apex back through septum into iv. Another character is the small size of the septal glands in vi, the corresponding pair in *Sp. Benhami* being larger.

Sparganophilus Smithi n. sp.

Definition. *Length 20 cm. by 3 1-2 mm. wide; number of somites 185. Dorsal pores, the most anterior one between i/ii, the most posterior one between xii/xiii. Clitellum dorsally 1-2 xvi–xxviii, ventrally xix–xxv. Tubercula pubertatis xix–xxvii, dorsal to spermiducal pores. Setæ 3 and 4 dorsal. Spermiducal pore between xviii/xix, ventral of tubercula pubertatis. Sperm-sacs in xi and xii. Spermathecæ 4 pairs in each of somites vii, viii, ix, and 1 pair in somite vi, slender, dorsal and lateral. Prostates 3 pairs in xxii, xxiii/xxiv. No muscular duct. Anterior nephridium xvi. Septal glands in iv, v, vi and vii about equal in size. No subpharyngeal parietal gland. Blood capillaries on nephridia numerous. Blood sinus in sacculated intestine not continuous. Hearts in viii, ix, x, xi, small. Color violet flesh, somewhat iridescent. Habitat, San Francisco, California.*

Sparganophilus sonomæ n. subsp.

Definition. *Length 20 cm. by 3 1-2 mm. wide; number of somites about 200. Dorsal pores. Clitellum dorsally xvii–xxviii, ventrally xvi–xxix. Tubercula pubertatis xix–xxviii, dorsal to spermiducal pore. Setæ 3 and 4 dorsal. Spermiducal pores between xviii/xix, ventral of tubercula pubertatis. Sperm-sacs in xi and xii. Spermathecæ, two pairs in each of vii, viii, ix; one pair in vi, not slender. Prostates 3 pairs in xxiii, xxiv, xxv, no muscular duct. Anterior nephridium in xvi. Septal glands in iv, v, vi, vii, about equal in size. No subpharyngeal parietal gland. Blood capillaries on nephridia numerous. Blood sinus in sacculated intestine not continuous. Hearts in viii, ix, x, xi, small. Color violet flesh, less iridescent than Sp. Smithi. Habitat, Sebastopol, Sonoma County, California.*

Sparganophilus Benhami n. sp.

Definition. *Length 17 cm. by 2 1-2 mm. in the posterior part of the clitellum; number of somites about 250. No dorsal pores. Clitellum, dorsally xv–xxiv; ventrally xvii–xxvi. Tubercula pubertatis xviii–xxii, ventral to spermiducal pores. Setæ 3 and 4*

Tab

Habitat

Length an

Setæ 3 and

Clitellum.

Tubercula

Spermiduc

Spermathe

Sperm-sacs

Prostates .

Anterior n
c

Septal glan

Parietal ca

Blood sinus
saccular

Hearts . . . .

Capillaries
phridia
body-wall

Table B. COMPARATIVE CHART OF SPECIES OF SPARGONOPHILUS. To face page 154.

	tamesis Benham.	*Eiseni* Smith.	*Benhami* n. sp.	*guatemalensis* n. subsp.	*carneus* n. subsp.	*Smithi* n. sp.	*sonomæ* n. subsp.
Habitat	England, Thames.	Illinois River, U. S. A.	Tepic, Mexico; 4,000.	Guatemala.	Mississippi River, Iowa.	Laguna Puerca, San Francisco, California.	Sonoma Valley, California
Length and width	7 to 10 cm.	18 to 20 cm. by 2 mm.	17 cm. by 2½ mm.	10 cm. by 2 mm.	9 cm. by 2 mm.	20 cm. by 3½ mm. (or less)	25 to 30 cm. by 3½ mm.
Setæ 3 and 4	Ventral.	Dorsal.	Dorsal.	Dorsal.	Dorsal.	Dorsal.	Dorsal.
Clitellum	½xv–½xxv.	Dorsally ½xv–xxv; ventrally ½xiv–xxvi.	Dorsally xv–½xxv; ventrally xvii–xxvi.	xvi–xxvi.	Dorsally xv–xxiv; ventrally ?	Dorsally ½xvi–xxviii; ventrally xix–xxv.	Dorsally xvii–xxviii; ventrally xvi–xxix.
Tubercula pubertatis	xvii–xxii, ventral to spermiducal pore.	½xvii–½xxii, ventral to the spermiducal pore and to the spermducts.	xviii–xxii, ventral to spermiducal pore and to spermduct.	Parallel ridges, xviii–xxii	.	xix–xxvii, dorsal to spermiducal pore.	xix–xviii, dorsal to spermiducal pore and to spermduct.
Spermiducal pore	Between xviii/xix, dorsal to tubercula pubertatis; so are the spermducts.	On anterior part of xix, dorsal to the tubercula pubertatis; so are the spermducts.	On anterior part of xix, dorsal to tubercula pubertatis.	. ...	... . .	Between xviii/xix, ventral to tubercula pubertatis.	Between xviii/xix, ventral to tubercula pubertatis.
Spermathecæ	Slender; one pair in each of somites vii, viii, ix; ventral in line with 3 and 4.	One pair in each of somites vii, viii, ix, dorsal in line with 3 and 4; slender.	Robust, trowel-like, with wavy outline; one pair in each of somites vii, viii, ix; dorsal.	Robust, trowel-shaped, with smooth outline, in vii, viii, ix.	Dorsal, one pair in each of somites vii, viii, ix. Apical end globular, not trowel-like.	Slender; four pairs (8) in each of somites vii, viii, ix, dorsal and lateral; one pair only in vi dorsal.	One pair in vi; two pairs (4) in each of somites vii, viii, ix; not slender.
Sperm-sacs	In xi and xii, minutely lobulate.	In xi and xii, minutely lobulate.	xi, xii, less minutely lobulate.	. .. .	xi and xii, lobulate, but not minutely so, as in Sp. Eiseni.	xi and xii, more lobulate than in Benhami, but less so than in Eiseni.	xi and xii, more lobulate than Benhami, but less than Eiseni.
Prostates	Not present.	Four pairs in xxiii–xxvi.	Four pairs, one each in xxiii–xxvi; a long muscular basal duct.	Four pairs in xxiv, xxv, xxvi, xxvii.	Present; four pairs in xxiii, xxiv and probably in xxv and xxvi.	Three pairs, one each in somites xii, xiii, xiv; no muscular duct.	Three pairs in xxii, xiii, xiv.
Anterior nephridia commence in	xiii.	xiii.	xii. The first two pairs smaller; the first large pair in xiv.	....	.....	xvi.	xvi.
Septal glands in	iv, v, vi; the posterior are the largest.	iv, v, vi. Those in iv and v about equal size; the one in vi is very diminutive.	iv, v, vi. About equal in size.	....	iv, v, vi; the one in vi the smallest.	In iv, v, vi, vii; about equal in size.	iv, v, vi, vii, about equal in size.
Parietal cœlomic gland in iii	Absent.	One pair of glands open in front of ventral setæ in iii; distal end extending into iv.	None.	None.	None.	None.	None.
Blood sinus in the sacculated intestine	Continuous.	Continuous.	Continuous.	....	....	Not continuous.	Not continuous.
Hearts	viii, ix, x, xi; not filling the cœlomic cavity.	In viii, ix, x, xi not filling the cœlom.	viii, ix, x, xi, not filling the cœlom.	viii, ix, x, xi, not filling the cœlom.	viii, ix, x, xi, completely filling the cœlom.	viii, ix, x, xi, quite small, not filling the cœlom.	viii, ix, x, xi, quite small, not filling the cœlom.
Capillaries on the nephridia and in the body-wall	Very numerous.	Very numerous.	Very few.	. . ..	Numerous and large; on the body-wall very numerous in the six anterior somites.	Numerous, giving the nephridia a pink color.	Very numerous.

are dorsal. Spermiducal pore on anterior part of xix. Sperm-sacs in xi and xii, not minutely lobulate. Spermathecæ one pair in each of vii, viii and ix are dorsal. Spermiducal glands or prostates 4 pairs in xxiii–xxvi, with a long muscular duct. Most anterior nephridium in xii. Septal glands in iv, v, vi of about equal size. A pair of subpharyngeal parietal glands not present. Blood capillaries on nephridia few. A continuous blood sinus in sacculated intestine. Blood glands many. Hearts in viii, ix, x, xi. Color violet, strongly iridescent. Habitat, Tepic, Mexico, 4000 feet.

Sparganophilus guatemalensis n. subsp.

DEFINITION. *Length 10 cm. by 1 1-2 mm. wide; number of somites 260. Dorsal pores none. Clitellum xvi–xxvi. Tubercula pubertatis xviii–xxii, parallel ridges. Setæ 3 and 4 dorsal. Spermiducal pores unknown. Prostates four pairs in xxiv, xxv, xxvi, xxvii. Spermathecæ one pair each in vii, viii, ix; wide free end, wide, flat, outline smooth. Hearts very strong. Color deep bluish violet iridescence. Habitat, Guatemala City.*

Sparganophilus carneus n. subsp.

DEFINITION. *Length 9 cm. by 2 mm. wide; number of somites 160. Clitellum dorsally 1-2xv–xxv. Tubercula pubertatis unknown. Setæ 3 and 4 dorsal. Spermiducal pores unknown. Sperm-sacs in xi and xii, lobulate, but less minutely than in Sp. Eiseni. Spermathecæ one pair each in vii, viii, ix dorsal; free end globular. Prostates unknown. Septal glands in iv, v, vi, the one in vi the smallest. No subpharyngeal integumental glands. Blood capillaries enormously large and many in the anterior six somites. Hearts very large in viii, ix, x, xi. Color reddish flesh, much darker when in alcohol than Sp. Benhami. Habitat, Mississippi River, near Clayton, Iowa.*

After these preliminary definitions I will now describe in detail the various species of Sparganophilus examined by me.

Sparganophilus Smithi n. sp.

Figs 120–122, 124, 129–39.

Habitat. This species is very abundant in a small lake or pond known as Laguna Puerca and situated between Lake Merced and Golden Gate Park at San Francisco. Adult form in June to October, more frequent in the latter month. It occurs at or near, above and below the water's edge, the earth being thrown up in abundance and in heaps. I have already referred to nonpresence of this species some ten years ago in the above locality.

EXTERIOR CHARACTERS.

Color. A brownish flesh with violet reflex, but much less so than *Sp. Benhami* or *Sp. guatemalensis.* In alcohol this species becomes much paler than either of the two just referred to, almost pure white, looses its irridescence entirely. In formalin the color is pale, the irridescence very faint, strongest on the clitellum, and hardly perceptible on any other part of the body.

Length varies some, but generally reaches in fully grown and largest speci-

mens 20 cm., while the width is about $3\frac{1}{2}$ mm. posterior to clitellum. This and the following species are the longest forms so far known of the genus. The worms are not remarkably lively when out of the ground.

Setæ. The couple 3 and 4 are distinctly dorsal, and it may be of interest to note that in all species found in America the dorsal portion of these setæ appear characteristic, while in *Sp. tamesis* the setæ 3 and 4 are ventral or sublateral. I can find no character in the form of the setæ in the various species. They are all slightly sigmoid, slightly hooked and devoid of ornamentation. There are no penial setæ and no modified setæ in any part of the genital region. The setæ of *Sp. tamesis* as figured by Benham are more hooked than those of my new forms.

Prostomium and *pygidium.* I cannot find any good characters in the form of these part in the respective species. The small pit in the prostomium of *Sp. tamesis,* described by Benham, is found in all the species. The pygidium varies greatly. While some specimens have the anal orifice elevated and dorsal others have it central. The shape and size of the last somite varies also to such an extent that no species character can be derived from it. I will then in the following not refer to these part in any of the species described below.

Clitellum. In all the species of this genus the clitellum is very large, occupying from 8 to 13 somites. In *Sp. Smithi* it is located as follows: dorsally, $\frac{1}{2}$xvi–$\frac{1}{2}$xxviii; ventrally, xix–xxv. Continuous all around the body. In all preserved specimens the body is bent towards the ventral side just at the clitellum, and special pains must be taken if a straight specimen is desired.

Tubercula pubertatis consists of a very elevated, continuous ridge, which is broken or depressed at the intersegmental grooves. It extends through somites xix–xxvii and is situated dorsally to the spermiducal duct and its pore. The ridge is further generally concave on the dorsal and convex on the ventral side. The ventral area between the two tubercula pubertatis ridges is thus much wider than in any of the other three new species described here. Anteriorly the tubercula pubertatis ridge is continued forward in a kind of semicircle which ends at the groove between somites ix/x. But these anterior ridges are much lower than the tubercula pubertatis proper, but nevertheless very sharply defined and distinct.

Spermiducal pore is situated between xix/xx, laterally to the setæ 1 and 2 and about three times as far from 2 as 2 is from 1. But the pore is ventral to the tubercula pubertatis ridge. This is an important characteristic and only shared with *Sp. sonoræ.* In *Sp. tamesis, Eiseni* and *Benhami,* the spermiducal pores are dorsal to the tubercula pubertatis ridge.

Oviducal pores are plain in front of setæ 1 and 2 on somite xiv.

Prostate pores externally not visible, but situated in front of setæ 1 and 2.

Somites. All the anterior somites are three-ringed, except i, ii, iii, which are smooth.

Dorsal pores. The most anterior pore is situated between i/ii, and the most posterior one between xii/xiii.

INTERIOR CHARACTERS.

Septa. Thickest septum is found between somites xi/xii. Anterior septa are gradually diminishing in thickness forward, and similarly the septa posterior to xi/xii are diminishing in thickness backwards. The most posterior thickened septum, the one between xiv/xv, is hardly thicker than the one next posterior. The central part of the thickened septa is very much thicker than the part near the body-wall. (fig. 127 *t.m.*) The septa correspond more to the intersegmental grooves than do those in *Sp. Benhami*. When the body is viewed in cross-section it will be seen that the septa are principally attached to the body-wall at four points nearly half way between the setæ (fig. 131).

Suprapharyngeal and septal glands. There are dorsal septal glands in iv, v, vi, vii, about equal in size, and ventral septal glands in v, vi, vii, also of about equal size. The latter are much larger than in *Sparganophilus Benhami*, and reach above the center of the body (fig. 120). In addition to these glands I find an accessory septal gland attached to the central anterior surface of septum ix/x, just above the intestine and extending downwards. This gland is closely attached at every point to the septum, and projects only slightly into the cœlomic cavity. In height this gland is not much thicker than the central part of the septum (fig. 132). Its free surface is very smooth and even. I could follow ducts with precipitated secretions running along the septum downwards towards the intestine, but its connection with the latter, if any, I could not ascertain. Beddard suggests that as the nephridia only commence in the thirteenth segments the septal glands described by Benham in *Sp. tamesis* are homologous with the nephridia. In all species of Sparganophilus investigated by me I find no such mucous glands as in Pontoscolex, only regular salivary glands, which open into the pharynx, and of the same structure as the supra-pharyngeal glands generally. These salivary glands in *Sp. tamesis* occur exactly in the same somites as in all other Sparganophilus species, viz.: iv, v and vi.

Body-wall offers no other characteristics, except that it is throughout of almost the same thickness, and not thinner along the dorsal parts of some of the central somites, as in *Sp. Benhami*.

Clitellum is continuous all around the body, but it is much thicker dorsally than ventrally. This thicker dorsal portion commences with the tubercula pubertatis, gradually increasing in thickness dorsally towards the median line, where it is four times thicker than at the ventral median line between the tubercula pubertatis. This refers only to the clitellar cells in the central clitellar somites. The long clitellar cells are confined to the latero-dorsal part, while the ventral part contains only the short clitellar cells, the point where the former cease being the tubercula pubertatis. This is the case in all the species examined by me.

Tubercula pubertatis. It has already been stated that they form a continuous ridge, only broken in the anterior two somites xvii and xviii. Their structure differs considerably from that of *Sparganophilus Benhami*. We find the tubercle cells less differentiated (fig. 138), and more resembling the short clitellar cells, of which they are only a variety. Another characteristic is the presence of a large blood vessel in

the center of the tubercle. The most interesting feature, however, consists in the presence of three or four arciform muscular bands which connect the opposite sides of the tubercular projection, and which, of course, serve to further push out the tip of the tubercle, or to relax it, as the occasion may demand. These bands are entirely confined to the clitellar cell layer, and penetrate to the very cuticle, to which at least some of the muscles are attached, while others seem attached to the cells themselves. Besides these epidermal arciform muscles, there are numerous cœlomic arciform muscles, which also penetrate the glandular layers and serve to connect the two sides of the clitellum on either side of the tubercula pubertatis (fig. 138). While the arciform muscles of the epidermal layer have been described by Cerfontaine in Lumbricus, they are by no means known from many species. Their presence varies considerably in different species of Sparganophilus, but they are especially numerous and strong in this one.

Œsophagus and *intestine.* As regards the general shape of the alimentary canal I can see no marked difference in the various species so far examined. Again as to structure I find two points worthy of mention. The chloragogen cells which are everywhere covering the intestine are much larger and more numerous in this species than in *Sp. Benhami*, covering as they do both tubular and sacculated intestine. Another point is the absence of a continuous blood-sinus. A continuous blood-sinus in the sacculated intestine has been described by Benham in *Sp. tamesis*, by Smith in *Sp. Eiseni* and is also found in *Sp. Benhami*, as will be recorded further on. In this species, *Sp. Smithi*, the sinus is not quite continuous, the respective blood lacunes are quite close and in places run together, but they are nowhere continuous in the same way as in the species referred to above. The sacculated intestine commences in xiii.

Spermathecæ (fig. 130). The most characteristic feature of *Sparganophilus Smithi* is the occurrence of numerous spermathecæ in at least three somites, while in one somite there is found only one pair. Seven adult specimens from Laguna Puerca were opened and agreed in the following arrangement and number of spermathecæ:

Somite vi: 2 spermathecæ, in front of or slightly dorsal to setæ 3 and 4.

Somites vii, viii, ix: 8 spermathecæ in each, in front of, slightly dorsal and lateral of setæ 3 and 4.

The location of these spermathecæ is not strictly constant as in some specimens, as well as in some somites of the same specimen, the spermathecæ were shoved a little dorsally or ventrally of setæ 3 and 4. One specimen possessed three spermathecæ on one side and four on the other side in the same somite, but all the other specimens possessed eight spermathecæ in each of the somites, except in vi where invariably only one pair was found.

These spermathecæ are very large (fig. 125), tall and slender, and viewed in cross-sections of their body they are seen to extend from one end of the cœlom to the opposite side, touching both body-walls. They are generally directed forward and crowding each other; they occupy nearly all of the available room in the somite. I believe there is no other case known in oligochæta where so many and so large spermathecæ are known to occupy the same somite. The size of the respective sperm-

athecæ varied some, but the general shape appeared quite constant within certain limits. The figures appended represent the spermathecæ taken from one specimen. There is a narrower muscular basal tube and a more swollen non-muscular chamber as usual, the structure of which offers no characteristics.

Sperm-sacs. Of the two pairs of sperm-sacs the anterior one in somite xi is much the narrowest in the direction of the median longitudinal diameter of the body. It is principally ventral in location, but extends upwards and joins the one from the opposite site. It is closely surrounded by a sperm reservoir without enclosing membrane. The sperm-sacs in xii are much broader and longer, but are generally only dorsal and do not enclose the intestine in any of the specimens sectioned. This relative size of the two pairs of sperm-sacs appeared constant. Somites ix and x are transformed into two very extended sperm reservoirs.

Ovaries in the various species are long and flat, not lobed, and in both longitudinal and transverse section offer to view a single undivided surface.

Oviducts are very broad and furnished each with an ovisac consisting of an invagination of the septum, which in all my specimens were filled with large gregarinæ, rarely containing any ova.

Ciliated rosettes are similar to those of *Sp. Benhami* in size. The spermducts run ventrally to as the tubercula pubertatis, about four times as far laterally and dorsally from seta 2, as 2 is distant from seta 1. The spermiducal pore is similarly situated ventrally to the tubercula pubertatis, This characteristic is in all the species only shared by *Sparganophilus sonomæ*. All other species are characterized by having the spermducts run dorsally as to the tubercula pubertatis. The spermiducal pore is similarly in *Sp. Smithi* situated ventrally to the tubercula pubertatis, and is found in the intersegmental groove between somites xix/xx.

Prostates or *spermiducal glands* (Beddard). There are three pairs of spermiducal glands, one pair each in somites xxii, xxiii, xxiv. One specimen possessed only one gland in xxiv, and there may possibly be found some variation in number when more specimens have been investigated. In all cases these glands were much smaller than in *Sparganophilus Benhami*, but otherwise almost similar in structure, except for the entire absence of the basal muscular duct. The glandular part was never large enough to be folded on itself lengthwise, but its tube was much twisted in the direction of its long diameter, often to such extent that cross-sections always showed the tube as three or four circular openings, surrounded by a wall two cells thick. The muscular basal part is absent, and the lower tube, where it enters the muscular layers, being very short, is surrounded by a thin layer of connective tissue. The whole organ in mature specimens projects only slightly above the body-wall, and the glandular part is in either diameter not any thicker than the body-wall.

Nephridia are in this species covered and perforated by numerous blood capillaries, to a much greater number than in *Sparganophilus Benhami*, but similar to what is described in *Sp. tamesis* and *Sp. Eiseni*. Otherwise the nephridia of the respective species appear to be of the same general size and structure.

Vascular system. The hearts begin in xi, and extend forwards to viii. In xii

and xiii there are no connecting vessels. In xiv to xvii we find the dorsal vessel enlarged and folded on itself in a zigzag manner. Both hearts and dorsal vessels are thickly covered with chloragogen cells. I have already pointed out the absence of a continuous blood sinus in any of the various parts of the intestine. All the various organs of the body are thickly covered with blood capillaries, especially so the nephridia, spermathecæ, the clitellum, in which strong capillaries separate every two or three rows of the large clitellar cells. In the center of the tubercula pubertatis is always seen a dense mass of larger and smaller capillaries.

A characteristic of the vascular system is also the great scarcity of blood glands, these being very numerous in *Sp. Benhami.*

Sparganophilus sonomæ n. subsp.

Figs. 123, 126.

Habitat. Creeks and springs around Sebastopol, Sonoma County, California. Adult specimens very numerous in April.

General Remarks. I consider *Sparganophilus sonomæ* as probably a subspecies under *Sp. Smithi*, which it resembles in most points, two of which are of the greatest importance, viz.: The position of the spermduct and spermiducal pore, and the duplication of the spermathecæ in several somites. But as long as I found the number of spermathecæ constant, and some other minor points of difference, I thought it best to describe this form more carefully, leaving the question of species or subspecies as a matter of choice, and for future consideration and study.

EXTERNAL CHARACTERS.

Tubercula pubertatis are the only external organs which differ from *Sp. Smithi.* While in *Sp. Smithi* they form a continuous ridge on either side, they are in *Sp. sonomæ* broken up in numerous tubercles, generally two or three on each somite (fig. 123). I believe there is another characteristic worthy of mentioning. The single puberty groove is in the center of the tubercle, while in *Sp. Smithi* there are two grooves, one at the base on either side of the tubercle. But I freely confess that I have not sectioned up a sufficient number of specimens in order to know if these points are really constant, or if not rather they are subject to considerable variation. My supply of mature specimens of *Sp. sonomæ* was very limited, but in all I found the tubercula pubertatis broken into a succession of little knobs, but all together forming a ridge in outline like that of *Sp. Smithi.*

INTERIOR CHARACTERS.

Spermathecæ. While in all the specimens of *Sp. Smithi* I found eight spermathecæ in each of somites vii, viii, ix, the subspecies possess them as follows: *Somite* vi: one pair with the pore in front of seta 4. *Somites* vii, viii, ix: two pairs (4) in each, with pores in front of setæ 4, and between 3 and 4. Each pair consists of two separate spermathecæ, one of which opens in the intersegmental groove in front of seta 4, while the other opens similarly in front of a line drawn $\frac{1}{3}$ the distance between setæ 3 and 4, the $\frac{1}{3}$ being towards 4 and the $\frac{2}{3}$ towards 3. Both pairs are, therefore,

dorsal. The direction of the spermathecæ is in the diameter of head to tail. They lie closely pressed to the body-wall. As regards size, the most anterior pair is the smallest, and the most posterior the largest.

Sparganophilus Benhami n. sp.

Figs. 97–119.

Habitat.—In the mud of springs, October, November, 1894. Tepic City, Territory of Tepic, Mexico, 4000 feet altitude. Of some fifty specimens collected only three were well developed as regards clitellum and tubercula pubertatis.

EXTERIOR CHARACTERS.

Color, reddish-violet, very strongly iridescent. The violet tint is very pronounced, much more so than in any other species that I have examined except *Sp. guatemalensis*, where the bluish-violet tint is very deep and intense.

Body. This is a long and slender species tapering towards the tail end. The cephalic lobe is superiorly not distinct from somite i, but there is a small pit on the boundary between the two. Somites i, ii, iii are less prominent. Somites iv to ix are strongly convex, but x to xv are much less so. The clitellar intersegmental grooves are only distinct between the ventral setæ.

Dorsal pores. The most anterior dorsal pore is seen between i/ii; the most posterior one between v/vi. There is a central pit in the dorsal side of somites i, ii, iii.

Clitellum, as in other species; the extent of the clitellum is different on the dorsal and ventral sides. This I think can best be expressed thus: dorsally, ½xiv—xxiv; ventrally, xvii—xxvi. The clitellum is continuous, but much less developed ventrally between the tubercula pubertatis than dorsally. This is also characteristic of the other species I have examined. Viewing the clitellum exteriorly, it appears as discontinued between the tubercula pubertatis ridges.

Tubercula pubertatis begin in xviii and end in xxii. Each one consists of a straight ridge on the top of which runs a groove parallel to the ridge. Posterior to the tubercula pubertatis proper the ventral part of the clitellum is concave deepening posteriorly and ending in a deeper pit in the posterior part of xxvi. Anteriorly the tubercula pubertatis ridges continue forwards almost straight and outside of the ventral setæ 1 and 2 to the center of xii, where they end in the region of the ventral setæ. These two almost parallel ridges are very thin and sharp, several times narrower than the tubercula pubertatis proper. They only appear in fully adult specimens, and are very characteristic. I believe that the underside of the clitellum will furnish good species characteristics if carefully noted. But in order to bring out this region properly the specimens must be slowly killed and then as rapidly as possible be passed through the alcohols into that of 96%. Formalin specimens do not show the region as well as alcoholic specimens.

Male pore or spermiducal pore is situated on the anterior ¼ of xx, just lateral to the tubercula pubertatis. The pore is not prominent, but may be readily seen.

Prostate pores are not prominent, but in adult specimens they may be seen in front of setæ 1 and 2 in somites xxiii, xxiv, xxv, xvi.

Ovipores are separate between somites xiii/xiv, or slightly on the anterior part of xiv.

Nephropores prominent in front of setæ 1 and 2 in all somites posterior to xii.

INTERIOR CHARACTERS.

Body-wall. In somites x to xiv the body-wall is much thinner on the dorsal side of the body than on the ventral side. As Benham does not mention this peculiarity in *Sp. tamesis*, and as I have not observed it in *Sp. Smithi*, I take it for granted that this character is peculiar to this species. The clitellum is complete, but much thinner on the ventral side between the setæ, as shown by figure 119, which represents the ventral body-wall in somite xix. It will be seen that the longitudinal muscular layer is several times thicker than the transverse layer. The strands are separated by irregular layers of granulated tissue of various thicknesses. The circular layer again consists of only one row of fascicles, each fascicle being tubular, and inclosing numerous irregularly distributed muscular fibers, strongly striate. When viewed in cross-section it becomes apparent that the strands of the longitudinal muscles are of varying thickness, the thicker ones being situated nearest the cœlomic cavity, from there gradually decrease in size towards the circular muscles.

Clitellar cells. The clitellar cells are especially interesting on account of their relationship to the cells of the tubercula pubertatis, which will be described later on. Figs. 107, 108 represent a longitudinal section of the body-wall in somites xxiii and xxiv. The muscular layers are much thinner, the clitellar cells are only developed in the vicinity of the prostates. Below the clitellar cells are seen long tubular cells, somewhat like those of the tubercula pubertatis, and between them are seen, now and then (fig. 107 *d.ch.*), the deeply staining discharge chambers of the clitellar cells. The unicellular glands, which are here very irregular, are entirely confined to the zone surrounding the intersegmental grooves. In fig. 108 is seen a more magnified part of the region close to the prostate. Only one unicellular gland, though of unusual size, is seen. It is a stray one, as they are rare in this particular zone. The structure of the clitellum of Sparganophilus has been well described by Benham in his paper on *Sparganophilus tamesis*, and I can only add a few points of interest. For studying the clitellar and tubercula pubertatis cells I have used principally the iron-lack Heidenhain process, but by adding a light tint of Ehrlich-Biondi to the ammonio-ferric-alum solution the most perfect differentiation may be had of the various clitellar elements. The clitellum in Sparganophilus contains the following various varieties of cells:

1. Regular epidermal cells, secreting the cuticle, furnished with oval nuclei. Even on the fully developed clitellum of *Sparganophilus Benhami* they occur all around, both on dorsal and ventral sides. Their inner ends are drawn out into one or more threads, some of which extend to the innermost margin of the epidermis (fig. 103, 1).

2. *Unicellular goblet* glands, entirely confined within the outer layer of the foregoing cells. They are very irregular as to size. These cells are the only ele-

ments in the clitellum which stain deeply with hæmatoxylin. These cells offer nothing characteristic of the species. They are the last to be affected by tropœolum and orange, their mucin remaining intensely blue. Their nuclei are compressed and placed in the posterior part of the cell in the triangular mass and extremity, staining black in the iron-lack (fig. 103, 2).

3. *Short club cells.* These are of very uniform size, their free ends forming a marked line all around the clitellum interior to the goblet cells. The free end of this cell is club-shaped and generally regular in outline. The heights of the individual cells are quite even, and, as these cells stain darker than the following kind, they form a marked contrast to all others. The granulation is coarse and regular, but does not stain readily with hæmatoxylin. It takes, however, deeply the red aniline stains. On the dorsal side of the clitellum these cells reach inward about $\frac{1}{3}$ of the whole width of the epithelium, while on the ventral side, they constitute the only so-called clitellar cells. The nuclei of these cells are oval and always prominent (fig. 103, 3).

4. The pre-eminently clitellar cells consist of several, 3 or 4, different lengths. This class of cells are in many genera, such as Lumbricus, etc., massed in columns, often very regular, and separated by septa. In Sparganophilus these cells are not arranged in columns, but distributed almost regularly all through the epidermis, of which they occupy about $\frac{2}{3}$ of the whole mass. At certain intervals, however, may be seen a thin triangular septa of connective tissue with nuclei, projecting downwards or outwards from the muscular layers, dividing this part of the epidermis in numerous irregular pyramidal masses, which latter are homologous with the columns in Lumbricus, etc. The nuclei of these clitellar cells are shrivelled up and situated far back in the triangular apex where the cellular plasma is especially agglomerated. There is no such granular secretion in this class as in the former, and they stain much less intensely than No. 3. These cells occur only dorsally to the tubercula pubertatis, and are entirely absent from the ventral side between the tubercula pubertatis.

5. Here and there we find intermediate varieties of oval and club-shaped cells longer and wider than the epidermal supporting cells and furnished with large round nuclei.

6. Connective tissue cells with large round nuclei, especially prominent between the circular muscular layer and the tall clitellar cells. At intervals this tissue forms triangular projections outwards, separating bunches of cells four or five wide and of different sizes. This tissue is generally accompanied by numerous capillaries.

Tubercula pubertatis. These organs are very prominent, and situated on a nearly continuous ridge occupying somites xviii–xxii. Benham has described this structure in detail in his species *Sp. tamesis*, and called attention to the fact that it is composed of long narrow cells, which are modified clitellar cells. In *Sparganophilus Benhami* these cells are of two kinds, as far as regards the form.

a Some which are very narrow, longer than the others, and narrowest at the free end. All of this class are grouped in such a way that they radiate outwards

towards and around a small concave pit or groove in the outer edge of the epidermis (fig. 105).

b. Interior to these taller cells are shorter and thicker cells, indicated as *b* in the above figure.

Exterior to these, the regular and characteristic tubercula pubertatis cells proper are seen numerous unicellular glands, the same as the goblet cells of the epidermis.

In addition to these glandular cells, I find at certain intervals a few sense cells opening out into the narrow pit or groove just referred to. They are everywhere very few in number, tall, narrow, with now and then the tip projecting through the cuticle into the shallow pit (fig. 105 *s. c. l.*) There is not a continuous row of these cells, but here and there are found bunches of half a dozen cells, opening close together. They do not seem strictly parallel, but bulge and diverge in such a way that in sections, which show the common cells parallel, rarely more than one single sense cell is in view to any great part of its length. This, together with the small number of these cells, is undoubtedly the reason why they are frequently overlooked.

In connection with these sense organ cells, I have re-examined the ventral papillæ found in *Argilophilus marmoratus*, and I find that these structures are really nothing but tubercula pubertatis nature, or at least sense organs furnished with sense cells, a description of which will be deferred to a future paper. As a general conclusion, I may state that the tubercula pubertatis are really sense organs, furnished with sense cells of the same nature as those found in other parts of the epidermis, and described by me in Benhamia, and by Vejdovsky in Rhynchelmis, by Cerfontaine and Langdon in Lumbricus, by Hesse in Lumbricus and Allolobophora, etc.

Septa. The septa are not all of the same thickness, neither is each individual septum of the same thickness throughout. The first distinct septum is found between iv/v. It is of regulation thickness, or as thick as septum x/xi and those following posteriorly. The anterior septa increase in thickness forwards and backwards in such a way that septa vi/vii, vii/viii are of about equal thickness, while those in front and behind these are thinner in proportion as they are more distant. The anterior five septa are much thicker in their central area, and thin out towards the periphery and body-wall, but even then, at the thinnest part, they are about four times thicker than the posterior septa. The six anterior septa do not strictly correspond with the segments, but are attached to the body-wall about one-fifth the distance forward from the posterior intersegmental groove.

Suprapharyngeal and *septal glands.* The glandular mass superposed on the pharynx and opening into it, is prominent, but situated far back, and with its lobes pointing forward, or in the same direction as the septal glands. The opposite is generally the case, and has been so in all other species examined by me.

Longitudinal sections show that the regular septal glands are present in three somites. The most anterior pair is in iv, immediately behind the suprapharyngeal glands, and not separated from the latter by any septum. The other two pairs are in v and vi. In longitudinal sections the suprapharyngeal glands are seen to be com-

posed of two distinct lobes of about equal size, one situated closely posterior to the other. This is also the structure of the septal glands in iv and v, but the one in vi is solid, consisting of only one lobe, when viewed in longitudinal section. The main lobes are situated on the same longitudinal muscular band, with their discharge ducts running forwards into the pharyngeal cavity. In each of the three somites there are two distinct glands on either side of the median line. One larger supraintestinal consisting of three parts extending laterally, and one smaller subintestinal. These latter ones also open into the pharynx, but into its ventral side, the pharynx thus being partially developed even on the ventral side. The discharge tubes and chambers are very large, and the latter occupy more than one-half the width of the pharyngeal wall. They stand very close together, and are all of about the same height and form (fig. 112). The dorsal wall of the pharynx is much thicker and denser than the ventral one, and the discharge chambers stand closer and are of more uniform size, more tubular. The discharge chambers on the ventral side are thicker, more pear-shaped and much fewer in number. Fig. 112 represents the lining of the dorsal wall of the pharynx; fig. 115 the ventral wall of the same, and fig. 114 the wall next posterior to the main dorsal section.

Œsophagus and *intestine.* The description given by Benham of the histology of the intestine of *Sp. tamesis* may in the main points be applied to this species. The œsophagus is cylindrical with parallel sides and slightly nipped by the septa. It is sparsely covered by chloragogen cells, which latter are more numerous on the intestine. The ciliæ of the inner epithelium are much longer in the œsophagus, and so are the epithelial cells themselves. Seen in longitudinal section (fig. 110) we find that the transverse muscles surrounding the œsophagus are more numerous and present in several rows, while in the intestine they are few and far between, and arranged only in one row. There is thus a distant approach to a gizzard in the œsophagus. The longitudinal muscular layer is reduced everywhere in the intestine to a single strand, but in the œsophogus it is double, sending out strands to the septa and to the mesenteric sac.

Blood sinus. Both Benham and Smith have shown the existence of a continuous blood sinus in the intestine of the species described by them. In the œsophagus of our present species we find only a vascular network and confluent smaller lacunes, but in the intestine proper we meet with a continuous blood sinus all around the epithelial cells. The radiated appearance of the blood in the sinus, as well as in the other vessels, must as Benham suggested be due to the crystalization of hæmatine. In *Sp. Benhami* and *Sp. Smithi* these crystals are so many and so heavy that they invariably destroyed the edge of the microtome knife and made sectioning most difficult. But the crystalization presents some peculiarities, and in places appears as if there was a mass of radiating fibers always from the side nearest the center of the body radiating towards the periphery, but never the contrary. In *Sp. Benhami* these crystals are much more slender than in *Sp. Smithi.* In the latter species their nature is not to be doubted. They are also found in the hearts, but more rarely in the main longitudinal vessels.

In the intestine we find between the inner ends of the epithelial cells a layer of connective tissue, strengthening as it were that side of the perienteric sinus (fig. 111). Both œsophagus and intestine are enclosed by a thin mesenteric sac, which is nipped by the septa (fig. 111, *mes.*) and pressed close to the chloragogen cells.

Spermathecæ. These are much broader than those of *Sp. Smithi* or *Sp. tamesis*, but resemble more those of *Sp. Eiseni* and *Sp. guatemalensis.* Their position in somites vii, viii, ix, is in the anterior part of the somite, opening in the intersegmental groove and pointing backwards. Their pores are in line with the dorsal couple of setæ, or 3 and 4. The muscular part is tubular, smaller, and consists of two layers, one inner of epithelial cells, one outer thicker, of circular muscles. The inner epithelial layer, which is a direct continuation of the epidermis of the body-wall, consists of very tall, narrow, columnar cells, while the thick muscular coating is a direct continuation of the circular muscular layer of the body-wall. The free end of the spermatheca is wavy and warty in outline, and consists of much shorter epithelial cells, simply covered by the peritoneum. The spermatheca is very broad and very flat (fig. 118).

Sperm-sacs. There are two pairs of lobulate sperm-sacs in xi and xii projecting from the anterior septum. They are situated principally dorsally, and resemble those of *Sp. tamesis*, but are much less lobulate than those, and very much less lobulate than the sperm-sacs of *Sp. Eiseni*, judging from sections of the species sent me by Prof. Frank Smith for comparison.

Large masses of free spermatogonia and spermatozoa are seen in front of the ciliated rosettes.

Ciliated rosettes (fig. 109) are large and very regularly folded. Each rosette sends out a long tubular lip into the sperm-sacs, in way which I have figured in fig. 119c. In a cross-sectioned specimen I found this lip far back in the posterior part of xii. The lower convolute lip of the funnel is almost absolutely regular, and similar in each of the four rosettes. The spermducts appear to resemble those of *Sp. tamesis* and *Sp. Eiseni.* The spermiducal pore is situated just outside of the tubercula pubertatis in the anterior part of xx, just as in *Sp. Eiseni.*

Prostates. Smith is the first to describe the prostates in Sparganophilus. In *Sp. tamesis* they appear not to be present, as Benham does not mention them. In *Sp. Benhami* there are four pairs opening in somites xxiii, xxiv, xxv and xxvi, in front of setæ 1 and 2. The prostates are constructed on the same principle as the prostates in Acanthodrilidæ and Cryptodrilidæ, and consist of two parts; one basal and muscular, one apical and glandular. The glandular part is tubular, straight or folded, of considerable length, but confined to one somite. The glandular part contains an inner epithelium, and surrounding it club-like glandular cells of varying lengths, giving to the surface of the prostate a wavy and irregular appearance. The prostates in this species differ from those of *Sp. Smithi* by having a muscular duct or basal part. This latter does not exist in *Sp. Smithi*, the glandular part in the latter species being immediately attached to the body-wall.

Nephridia. There is undoubtedly some difference in the location of the most

anterior nephridia in the various species. In *Sp. Benhami* the most anterior pair is in xii, but they are smaller than those in xiii. In xv we find the first very large nephridium covered with a thick cœlomic cell mantle. This mantle covers the ducts; sometimes we also find a mass of similar cells attached to the nephridium as a rounded, nearly separate mass, only connected with the nephridium by means of a very narrow part. Owing to the great opaqueness of the nephridia, I have not been able to make out the run of all the canals, and can illustrate only a little more than the outline of the organ. It appears, however, that some of the canals are doubled. The outlet duct is very heavy, wide, and its walls are thick. It runs far up into the windings. There is a bridge, and I can distinguish all the various principal parts described by me in the nephridium of Pontodrilus. There are comparatively few blood vessels on the nephridia, and in this respect the species differs from *Sp. Eiseni* and *Sp. Smithi*, in which the nephridia are thickly covered and penetrated by capillaries, causing them to be of a deep pink color. As regards size, the nephridia are as high as the diameter of the cœlom. The nephropores are in front of setæ 1 and 2, and very wide.

Vascular system. Benham's description of the vascular system of Sparganophilus is so complete that I can add but little; the various species seem to agree to a very great degree. *Sp. Benhami* is distinguished by a scarcity of capillaries on the various organs of the body, such as clitellum, nephridia, etc., while in *Sp. Smithi* and *Sp. Eiseni* capillaries are so abundant that they, for instance, almost obscure the nephridial surface. The crystalization of the blood has already been described. It is found in all the vessels of the body, but especially in the mesenteric blood sinus. I have found swimming free in the blood two distinct cell elements, some of which are very large—possibly leucocytes, while others are extremely minute, more round and dense—possibly erythrocytes. But as their description requires more time and study, I will defer it to a separate paper.

The walls of the blood vessels present a banded appearance, caused by parallel bands of thicker tissue, furnished with large circular nuclei, arranged in rather regular rows.

A characteristic feature of the capillaries of this species are the numerous blood glands, similar to those I have described in Pontodrilus and Argilophilus. They are especially numerous in the nephridia and in the septal glands. They also contain a large number of nuclei.

Sparganophilus guatemalensis n. subsp.

Habitat. Guatemala. While in this Central American State several years ago I found a great number of specimens pertaining, as I believe, to at least three distinct species of Sparganophilus. These, as well as my other oligochætological collections made there, were mostly destroyed by accident, few specimens being saved. These are now not in good condition for description, and this must account for the imperfect data I am able to furnish for all species now described from Guatemala. I found Sparganophili in that country in the most varied localities—City of Guatemala at Los Baños, Los Arcos, Laguna Amatitlan, Coban, Panzos Ysabal, Dueñas, etc. The present form is from Los Baños and from Coban.

GENERAL REMARKS.

I consider this a subspecies of *Sparganophilus Benhami*, at least until a closer investigation of better material may reveal other characters, if any there are. *Sparganophilus guatemalensis* is one of the smaller species about 10 cm. long by 2 mm. wide; the specimens were considerably stretched. Color is deep flesh, with an intense deep, dark violet lustre, much darker than in any other species and well preserved in alcohol, in which the specimens appear blackish violet.

Setæ are lateral and dorsal.

Clitellum extends from xvi–xxvi, but cannot be well defined on the ventral side. The *tubercula pubertatis* are in the shape of two parallel ridges extending from xviii to xxii or specimens from Patal and Coban, which I take to belong to the same species as those from Los Baños in the City of Guatemala.

INTERNAL CHARACTERS.

Of these I could only distinguish a few. The *spermathecæ* are in three pairs, one each in vii, viii, ix, opening in the anterior intersegmental groove. The apical end in the fully developed spermatheca is very wide, flattened like a mason's trowel. Several of the spermathecæ possessed a slit or opening in the apical end which communicated with a longer or shorter sac, continuous with the exterior lining of the rest of the spermatheca. It is possible that this is only a result of maceration, as I have seen nothing like it in other species of Sparganophilus, and it is not probable that we here have an analogy with the spermathecæ of Enchytræus or Sutroa, where this organ communicates with the intestine.

Prostates are found in four pairs and situated in somites xxiv–xxvii or one somite further back than in *Sp. Benhami*. This in specimens from Sapote. If this character holds good it is one of considerable importance.

Hearts were in viii, ix, x, xi strongly developed, but not filling the cœlom. Some of the Guatemala Sparganophili possessed only three pair of hearts in somites ix, x, xi, with the ventral vessel branching in xv/xvi. Those were specimens from Los Arcos. Others again from Amatitlan possessed the hearts in x, xi, xii, xiii, with the ventral vessel divided in xv/xvi, while those from Los Baños, Guatemala City, had the ventral vessel branched in xiv/xv. I believe those from Amatitlan and Los Arcos belong to different species, but, as all the specimens are lost, I can only call attention to the differences and to the importance of further investigations.

Sparganophilus carneus n. subsp.

Habitat. Mississippi river near Clayton, Iowa, in soil at the water's edge, under pieces of boards and lumber. Numerous specimens at end of August, 1890, only few of which were adult.

General remarks. It is probable that this is only a northern form of *Sparganophilus Benhami*, from which species it differs principally in the form of the spermathecæ, and by a much lighter color. The specimens at my command were not in proper condition and the shape and position of the tubercula pubertatis could not be made out.

My object is merely to call attention to this form which after all may be more distinct as more of its structure is known. In regards to the form of the spermathecæ it differs much more from *Sp. Benhami* than does the other subspecies *Sp. guatemalensis*. It is also much smaller.

CHARACTERISTICS.

Color is much lighter, more flesh and less violet than that of *Sp. Benhami* and *Sp. guatemalensis*, and the irridescence more faint. The species is smaller than *Sp. Benhami*, being about 9 cm., about one-half the size of that species.

Clitellum in the most developed specimen occupied xv–xxiv ventrally, dorsally it could not be properly defined. Prostates present with certainty in xxiii, xxiv, but owing to the somites being torn in xxv, xxvi I could not with certainty ascertain their presence there.

Setæ are similar to those in *Sp. Benhami*. The anterior xxii somites have much larger setæ than the other, except the most posterior ten. The setæ increase in size from somite ii to somite xv, then diminish backwards to xxiii, in which somite they are smaller yet, this size continuing to the tail, where at about ten somites from the anus the setæ again begin to increase. There is no parietal gland in somite iii as in *Sp. Eiseni*, and this is the chief reason why I class this species under *Sp. Benhami*. The *spermathecæ* are in three pairs and open in front of 3 and 4 dorsally. Their shape resembles much more those of *Sp. Eiseni* than they do those of *Sp. Benhami*. The apical end is globular and very much larger than the basal part. The spermathecæ are not trowel-like. I give some outline drawings of the spermathecæ taken from one and the same individual.

Sperm-sacs are very large in xi, xii, the one in xxii projecting into xxiii filling the somite also. The sperm-sacs are coarsely lobulate, much less so than in *Sp. Eiseni*.

The *capillaries* resulting from the lateral integumental vessels are very large in the anterior six somites. The hearts also are very large and seem to fill all available space on the cœlomic cavity in viii, ix, x, xi.

Deltania Troyeri Eisen, n. var. crassa.

Figs. 142, 143.

DEFINITION. *Size 45 mm. by 2 1-2 mm. Septal glands in v and vi, about twice as thick as the septum. Spermathecæ each with two diverticles, which have the apical ends globular and inflated. Prostates thick, with the glandular part about 1 1-2 times longer than the thin muscular duct. Habitat, Baja California.*

In other respects like the type, judging from two dissected specimens.

Habitat. Of this variety I possess only three specimens, from Ensenada de Todos Santos, in the northern part of Baja California, on the Pacific Coast side. They were taken in the same locality as *Aleodrilus Keyesi*, in the pure sand in the creek bottom, in a spot which had been kept moist by the accumulation of some sacks and rubbish. The specimens became strongly contracted, on account of the necessity of immediately placing them in alcohol.

EXTERNAL CHARACTERS.

The variety resembles the main form in most respects, but is much larger, especially thicker. The contracted specimens were as long as the longest of the main form from San Francisco, when fully extended, and twice as thick, and must, when alive, have measured 45 mm. by 2½ mm. Other external characters agreed exactly with those of *Deltania Troyeri* type from San Francisco, California. The deltoid arrangement of the ventral setæ in the genital region was identical, which satisfies me that we in this arrangement have most important species characters between the species of this genus.

INTERNAL CHARACTERS.

The variety differs from the type in two particular points.

The *septal glands* are present only in two somites, v and vi, and are exceedingly thin, or about one-fourth as thick as those of *D. Troyeri* type. This refers to those superior to the intestine. Those below the intestine I could not discern, as no sections were made. The glands were lamellæ-like, and only about twice as thick as the septum.

The *spermathecæ* were thicker than those of the type, with more inflated diverticula.

The *prostate* was thick, and its glandular part about 1½ times longer than the very thin muscular duct. Two or three fully developed penial setæ with each prostate.

Deltania Troyeri Eisen, n. var. lagunæ.

Figs. 144–147.

DEFINITION. *Size 32 mm. by 1 1-2 mm. No copulatory papillæ. Setæ a and b next posterior to clitellum, reach their final distance in the fifth somite posterior to clitellum. Spermathecæ in ix twice as large as those of the type, contracted at center, apical part swollen. Prostates more slender than in the type. Large ovisacs. Habitat, Baja California, Sierra Laguna.*

DETAILED DESCRIPTION.

Habitat. The exact locality in the Cape Region of Baja California and Sierra Laguna is a camping-place called La Joya. There, where the trail crosses the creek the water had backed up behind some fallen logs causing a miniature mudflat covered with leaves and sediment. The specimens were found in the rotten wood and under the decayed leaves in the mud. Altitude about 5500 feet.

EXTERIOR CHARACTERS.

The average specimen is larger than the type from San Francisco, the largest specimen of the latter being smaller than the average mature specimens of the variety *lagunæ*. The two round copulatory palpillæ figured by me from *D. Troyeri* are not seen in the variety. The sacs of penial setæ in several dissected specimens possessed each two penial setæ fully developed, one having three, but of which one

was undeveloped. One of the setæ is a trifle more curved than the other. The point of each penial seta shows a slight and indistinct ornamentation (fig. 144). Since my first description of *D. Troyeri* I have found some more mature specimens at the old locality in San Francisco. One of these specimens possessed two penial setæ in each sac, both slightly sigmoid, with trace of ornamentation at the free apex. In the variety *lagunæ* the ornamentation is more distinct.

Common setæ resemble the type, but setæ *a* and *b* next posterior to clitellum reach their proper and final distance from each other only in the fifth somite posterior to clitellum, while in *D. Troyeri* type they reach the final distance in the third somite posterior to clitellum.

INTERNAL CHARACTERS.

Spermathecæ are much larger in the variety *lagunæ*, or about twice the size of those in *D. Troyeri*, with the main body distinctly contracted at the center, and with the apical part much enlarged. The diverticula are distinctly tri-digitate and reach up to the narrow contraction of the main sac.

Prostates or spermiducal glands are much more slender and longer than in *D. Troyeri* type, and generally but not always confined to one somite.

Ovisacs are two, projecting from the septum xiii/xiv into xiv, occupying the largest part of the cœlomic cavity in the latter somite. The structure of the ovisac is characterized by numerous trabecula forming an extensive system of round pockets of various sizes. Where there are no pockets there are solid zones of round or slightly oval nuclei (fig. 147) imbedded in a dense mass of tissue without distinct cell-walls.

PHŒNICODRILUS Eisen.

The finding of a new species of this genus enables me to more properly define it. The genus was originally based on the absence of a prostate at the male-pore, there being, however, a short muscular atrium, in which opened the spermduct. The type was *Phœnicodrilus taste*, a species from the Cape Region of Baja California. The new species described below under the name of *Phœnicodrilus tepicensis* possesses a much more developed atrium, in shape and structure resembling a spermatheca. There is a total absence of glandular cells, such as are found in prostates, the whole atrium being muscular. There is besides another difference between Phœnicodrilus and Ocnerodrilus, though of much smaller importance. In Phœnicodrilus we find a large number of muscular fascicles divided in three paired groups in somite xvii, radiating from the male pore. In Ocnerodrilus these arciform muscles are few in number. In Phœnicodrilus these muscles are so thick and numerous that the atrium itself can only be seen in sections, not by suface view of the inner side of the body-wall.

Through the possession of a muscular atrium this genus comes rather close to Nannodrilus Beddard. This genus, of which so far only one species is known from Africa, possesses a muscular bursa copulatrix, in which opens separately the anterior prostate and the anterior spermduct. The great similarity between the atrium in Phœnicodrilus and the bursa copulatrix of Nannodrilus is very striking, especially as

the spermducts in Phœnicodrilus also open into the atrium. But the question that still remains to be settled is this. Is the atrium in Phœnicodrilus a modified bursa copulatrix, or is it simply the remains of deteriorated prostate. The absence of a penis in Phœnicodrilus makes the latter alternative seem most probable. While in Ocnerodrilus the reduction of the prostate consists in the loss of one layer of glandular cells in the apical part, this reduction has proceeded further in Phœnicodrilus, the whole glandular apical part here being wanting.

The principal differences between the genera Ocnerodrilus and Phœnicodrilus are then as follows:

Ocnerodrilus. A prostate of varying size is always present at the male pore. This prostate consists of two parts, one glandular, lined by a single layer of cells, and one muscular basal part.

Phœnicodrilus. No prostate, only a short or rudimentary muscular atrium, in the lower part of which opens the spermduct.

Phœnicodrilus taste Eisen.

Definition. *Atrium rudimentary, muscular and bulbous, only about twice as thick as the spermducts. No ovisac. Spermathecæ covered with warty excrescences. Arciform muscles in xvii comparatively few.*

This species, which I first described from the west coast of the Cape Region of Baja California, has since been found by Messrs. Eisen and Vaslit in two widely separated localities. It was found in great numbers at Miraflores, on the east side of the Sierra of the Cape Region, some 30 miles north of San José del Cabo, together with *Ocnerodrilus Beddardi*, Sept., 1894. It was, however, quite unexpected to find this species also common in garden soil at San Blas, the seaport in the territory of Tepic, several hundred miles south of the Cape Region peninsula. I can find no differences in the anatomy, nor in the exterior of the specimens from these respective localities. The small copulatory papilla in somite xiv, lateral to the oviduct, is present in all. So are the numerous muscles in the copulatory region around the male pore.

Phœnicodrilus tepicensis n. sp.

Figs. 155–160.

Definition. *Atrium about twice as long as the body wall, but hidden by arciform muscles in somite xvii. A median ovisac in xiv/xiii. Spermathecæ entirely smooth, without warty excrescences. Arciform muscles in xvii very numerous.*

Habitat. Numerous specimens in and around the city of Tepic, territory of Tepic, Mexico, 4000. In moist soil under logs, in gardens, etc. November, 1894. Found together with *Acanthodrilus Vasliti.* Only few specimens were adult in November.

EXTERIOR CHARACTERS.

Size 4 cm. by $1\frac{1}{2}$ mm. Number of somites 75.

Clitellum incomplete, comprising somites xiii–xix.

Setæ strictly paired, sigmoid plain. The pair 1 and 2 is wanting in xvi.

Spermathecal pores in ix in front of setæ 1 and 2.

Oviducal pores in xiv in front of setæ 1 and 2.

Spermaducal pores in the center of xvii, where otherwise would be the setæ 1 and 2. A small copulatory papilla around each male pore, but it is not connected with a zone. No dorsal pores.

INTERNAL CHARACTERS.

Muscles. Numerous arciform muscles in the copulatory region, but especially in xvii, connecting the copulatory papillæ with the body-wall in line with setæ 3 and 4. These arciform muscles are arranged in three distinct groups. The central group, which branches out fan-shaped from the inner surface of the copulatory papillæ, is by far the largest, consisting of about 10 to 12 distinct fascicles. Anterior to this is another group of 6 to 7 fascicles, and in the posterior part of the somite we find a swollen group of about 5 fascicles. To what extent these vary as to numbers, etc., is uncertain, but my observations in *Phœnicodrilus taste* are that they are quite constant, and might be used as valuable characters in determining the species, as with a change in the muscular strands is also connected one in the exterior copulatory zone. Between xvii and xiii, as well as between xvii and xix we find several pair of arciform muscles in each somite.

Septal glands are well developed. The suprapharyngeal glands are very long and extend far backwards. The septal glands in the following somites diminish posteriorly.

Spermathecæ. One pair in ix open between viii/ix in front of setæ 1 and 2. Form sac-like, very thin walls, pellucid, outline smooth, without any warty diverticula. No distinction between a muscular and glandular part. The size is large, about as long as the somite is wide.

Testes, ovaries and ciliated rosettes not characteristic.

Ovisac. There is a median ovisac in xiii/xiv (fig. 157), consisting of a pouching backwards of part of the septum. This is the only species in the three genera, Ocnerodrilus, Gordiodrilus and Phœnicodrilus, which possesses an ovisac.

Spermducts are of the same width throughout, without any muscular enlargement near the male pore. The two ducts run together, but their lumens are separate until they reach the muscular atrium, where, just before they enter it, the two lumens fuse into one (figs. 158, 159).

Muscular atrium. As has already been stated the usual prostates in Ocnerodrilus are replaced by a pair of muscular pouches, entirely covered up by the numerous arciform muscles. There are no glandular cells, and these atria can best be compared to the basal muscular parts of the Ocnerodrilid prostate only they are very much thicker, and consist entirely of muscular cells with the lumen in the body-wall lined by columar epithelium. In the main pouch this epithelium consists of short cells with round nuclei, around which extends a thin muscular layer, which becomes wider at the base. This atrium is very short and cannot readily be seen when the opened

body cavity is viewed from the interior surface. It is attached to the at this point very much thickened body-wall (fig. 158) by numerous muscles and connective tissue. The various species of Ocnerodrilus, especially those with short prostates, require reinvestigation in order to ascertain the structure of the prostates. Should intermediate forms be found it might become proper to merge the two genera into one.

Nephridia. Those anterior to clitellum are not covered with a cœlomic cell mantle, while those posterior to the clitellum are surrounded by a very thick one. The structure of the nephridia appears to be similar to those of *Phœnicodrilus taste*, at least in a general way.

LITERATURE REFERRED TO.

Benham, W. B. A new English Genus of Aquatic Oligochæta (Sparganophilus), belonging to the family of Rhinodrilidæ. Quarterly Journal Micros. Science, vol. xxxiv.

Benham, W. B. Report on an Earthworm collected for the Nat. Hist. Dept. of British Museum by Emin Pasha in East Africa. Journal Roy. Microsc. Society, February, 1891.

Beddard, Fr. E. Two New Genera, Comprising Three New Species of Earthworms from Western Tropical Africa. Proceedings Zoological Society, 1894, pages 379, etc.

Beddard, Fr. E. A Monograph of the Order of Oligochæta. Oxford, 1895.

Cerfontaine, P. Recherches sur le Systeme Cutané, etc., du Lombric Terrestre. Archives de Biologie, x, 1890.

Eisen, G. California Eudrilidæ. Memoirs Cal. Academy of Sciences, vol. ii, No. 3.

Eisen, G. Pacific Coast Oligochæta I. Memoirs Cal. Acad. of Sciences, vol. ii, No. 4.

Eisen, G. Anatomical Studies on New Species of Ocnerodrilus. Proceedings Cal. Academy of Sciences, ser. 2, vol. iii.

Garman, H. On the Anatomy and History of a New Earthworm (Diplocardia communis). Illinois State Laboratory of Nat. History, iii, 1888.

Hesse, Richard. Uber the Septaldrüsen der Oligochæten. Zoological Anzeiger, No. 456, 1894.

Hesse, Richard. Zur Vergleichende Anatomie der Oligochæten. Zeitschrift f. Wissensch. Zoologie, 1894, pages 406.

Horst, R. Earthworms from the Malay Archipelago. Zoolog. Ergebn. e. Reise in Niederländ. Ost-Indien. Dr. Max Weber, B. ii, Leiden, 1892.

Langdon, F. E. Sense Organs of Lumbricus. Journal of Morphology, vol. xi.

Michaelsen, W. Oligochæten des Nat. Hist. Museum, Hamburg, iii.

Michaelsen, W. Oligochæten des Nat. Hist. Museum, Hamburg, No. iv.

Michaelsen, W. Regenwürmer der Thierwelt Ost-Afrikas, Bd. iv, Berlin, 1895.

Rosa, Dr. D. Annailen d. K. K. Nat. Hist. Hofmuseums. Die Exotischen Terricolen, Wien, 1891.

Rosa, Dr. D. Contributo allo Studio dei Terricoli Neotropicali. Accademia Reale delle Scienze di Torino, 1895.

Smith, Frank. A Preliminary Account of Two New Oligochæta from Illinois. Bulletin Illinois State Laboratory of Nat. History, vol. iv, 1895.

Ude, H. Beitrage zur Kentniss auslandischer Regenwürmer. Zeitschr. f. Wissens. Zoologie, 57, 1894, page 69, etc.

Vejdovsky, Fr. Organogenie der Gordiodrilen, Zeitschr. f. Wissensch. Zoologie, Bd. lvii, p. 642.

Vejdovsky, Fr. System u. Morphologie der Oligochæten, Prag., 1884.

Verson, E. von. Zur Spermatogenesis, Zool. Anzeiger, xii, 1889, p. 100.

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE XLVI.

BENHAMIA PALMICOLA.

0. Longitudinal section of the genital somites.

BENHAMIA NANA.

1. A specimen; natural size.

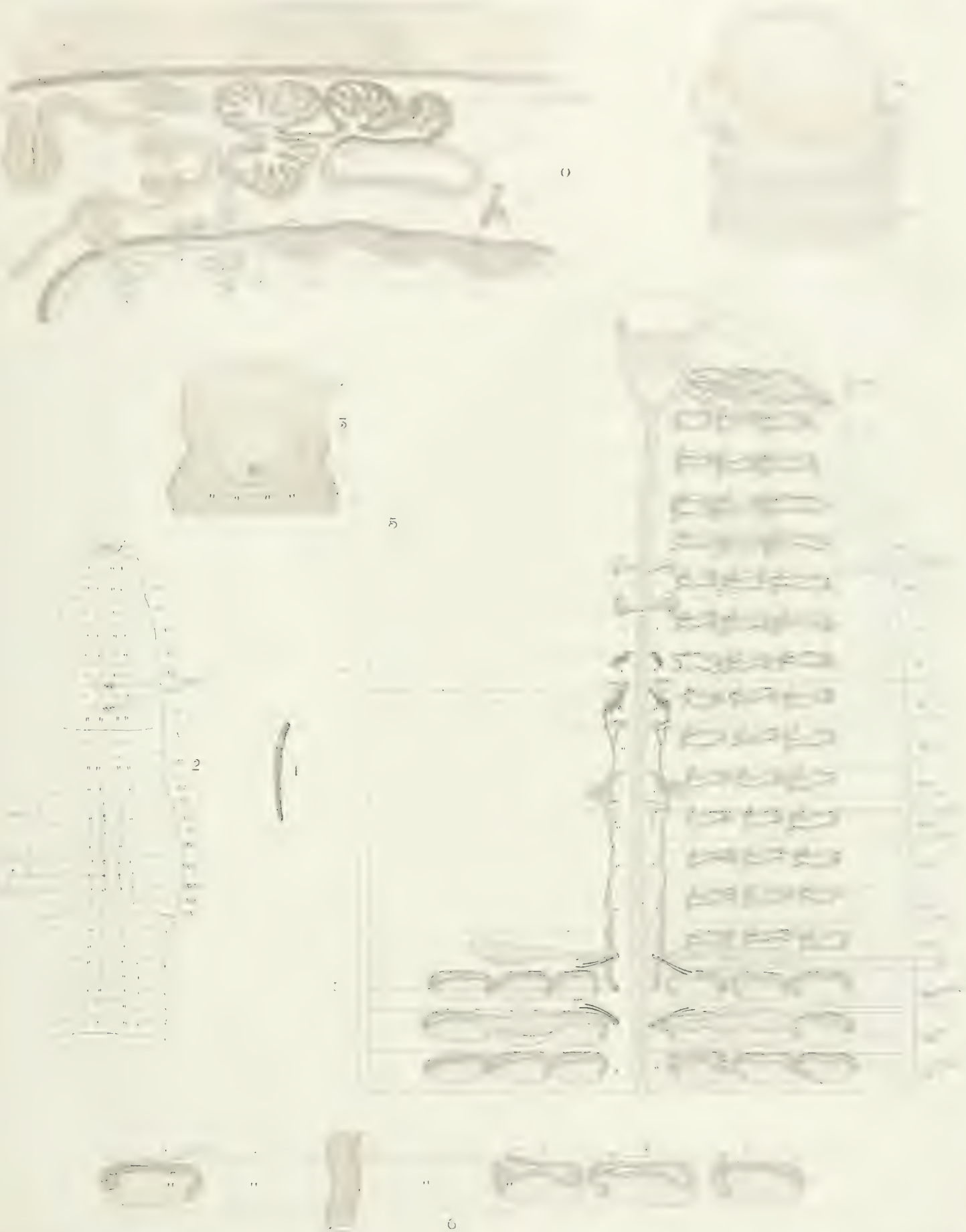
2. The ventral side of the anterior somites, showing the exterior pores, etc.

3. The ventral side of the most anterior somites, showing the everted pharynx and the very narrow somite i, etc.

4. Side view of the same somites.

5. The anterior twenty somites laid open, exposing the various organs, etc. The alimentary canal is removed and the whole figure is held somewhat schematic. *atr.* thickened part of the spermducts.

6. Part of a posterior somite viewed from the inner side, showing the relative position of setæ and nephropores. 1, 2, 3, 4 refer to the setæ; a, b, c to the nephridia.



Benhamia papillata Fig 0. Benhamia nana Figs 1 to 6.

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. ory. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE XLVII.

BENHAMIA NANA.

7. A somewhat diagrammatic figure representing the anterior part of a specimen sectioned lengthwise, composed from several sections, showing the location and size, etc., of various organs. *x*. beginning of the muscular part of the spermduct.

8. Cross-section through the most anterior part of the body, through prostomium and buccal division, showing the pharyngeal glands in four distinct divisions. The section is anterior to the cephalic ganglion.

9. Section posterior to the former, through somite ii.

10. Section through somite vii.

11. Section through somite xiv; the calciferous gland with the intestine belongs to somite xiv; the ovary to xiii. The section passes just in front of the oviduct. *x*. the limit of the clitellum.

12. Section through somite xvi. The calciferous diverticula belong to somite xv.

13. Section through somite xvii and the anterior prostate pore. *x*. ending of clitellar cells.

14. Section through somite xx, showing the typhlosole.

15. Longitudinal section through the most anterior part of the body, showing the projected pharyngeal division with the gland ducts. *phx*. pharyngeal division. The dark line indicates the row of discharge chambers of the ducts from the glands. A more magnified view is represented in fig. 18.

16. A couple of strands of the unicellular salivary septal glands with their muscles.

17. Some of the septal unicellular glands more highly magnified.

18. Section through pharynx, showing the discharge ducts and pockets from the septal and pharyngeal glands.

19. Lining of the œsophagus below the salivary glands, showing its exceeding thinness.

20. Longitudinal section through the body-wall, showing the sense organ region in the equatorial line of the somite. *c. e.* central lumen or organ proper, in which are seen the sense cells, together with nuclei of supporting cells. These supporting cells are surrounded by peculiar lunate or sac-like transparent cells, also found in the sense organ of the pharynx. *n. c.* nerve cells and their nuclei.

21. Longitudinal section through gizzard, showing glands with their discharge tubes and small terminal pockets.

22. Section through the alimentary canal between the two gizzards, showing glands. *c*. cluster of lunate cells surrounding a lumen.

23. Longitudinal section of the tubular intestine from somite xvi. *u. c.* unicellular glands. *bl. s.* blood sinus.

24a. One of the lobes of the typhlosole, showing distribution of glands, some of which are dark staining, others not.

24b. Section through the intestine adjoining the typhlosole.

25. Two glandular cells from the former section, more magnified. The two glands belong to different types.

26. A pair of calciferous diverticula from xiv. The right-hand gland is much smaller, which is an exception, as generally they are of equal size.

27. Detail of a section of lamella from one of the anterior calciferous diverticula.

28. Two cells more highly magnified.

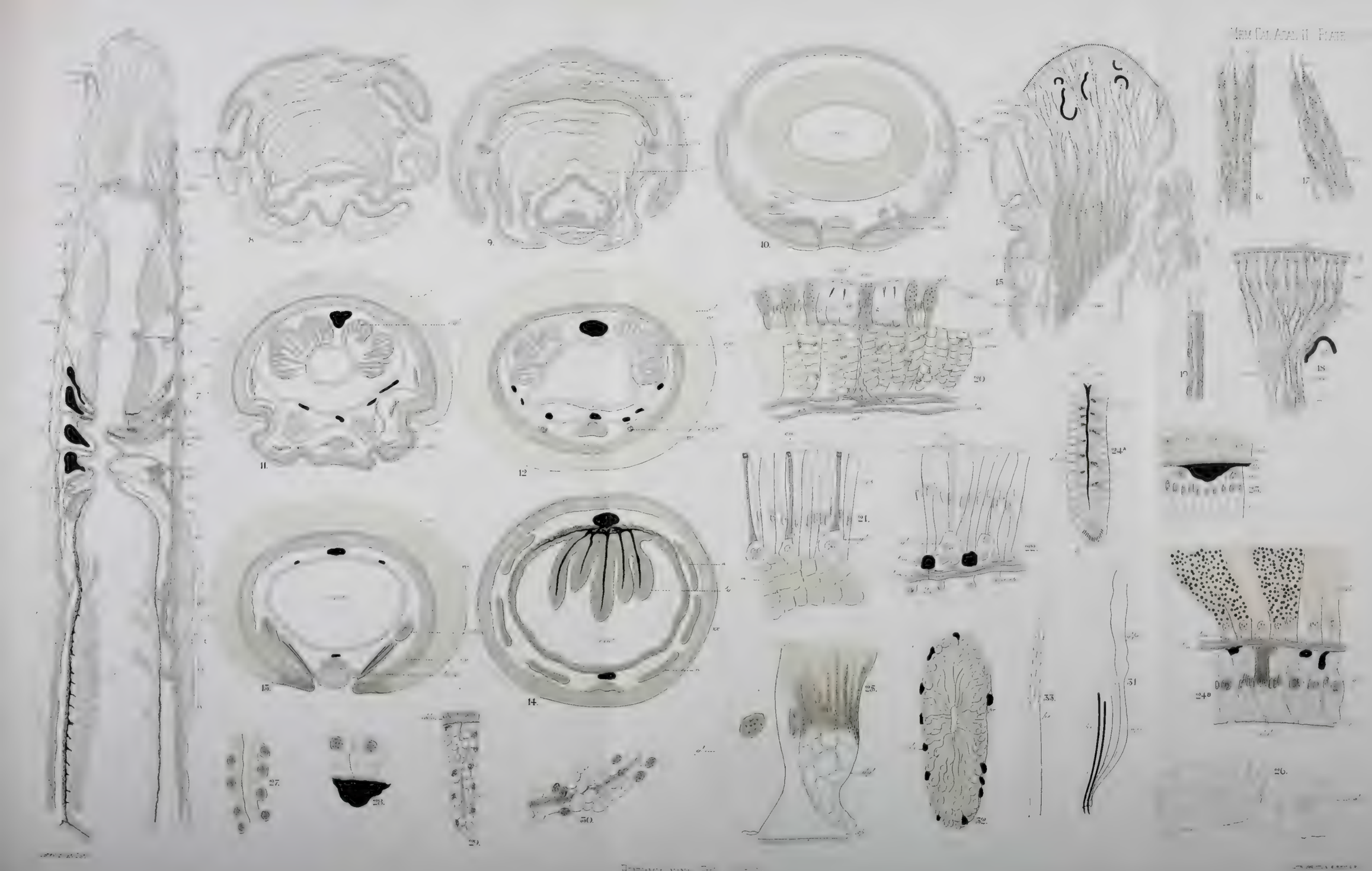
29. Section through one of the posterior calciferous diverticula.

30. Part of the same more highly magnified. Zeiss Hom. Im. Eyp., 2.

31. One of the prostates with sac with penial setæ.

32. Cross-section through glandular part of prostate.

33. Part of a penial setæ near the apex; the latter is broken.


8.
9.
10.
15.
16.
17.
11.
12.
20.
18.
19.
24A.
25.
21.
22.
14.
15.
24B.
26.
27.
28.
29.
30.
31.
33.
25.
32.

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellar glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE XLVIII.

BENHAMIA NANA.

36. Section through one of the prostate pores, showing prostate, sac with penial setæ and the thickened spermduct. *x*. at this point the clitellar cells cease. *c. t.* connective tissue between the two muscular layers.

37. Cross-section of the thickened part of the spermduct, showing the two lumens separate.

38. Section through the muscular part of the prostate, showing the epithelium and some of the muscles nearest the lumen.

39. One of the posterior nephridia; the shaded sac-like part represents the cœlomic mantle. It is generally covered with capillaries to such an extent that the structure of the organ is obscured. *br.* bridge. *nec.* neck of narrow duct. *spr.* spur. *o. f.* anterior fold. *p. f.* posterior fold.

40. One of the anterior nephridia, showing absence of cœlomic glands, also the arrangements of blood vessels.

41. Part of the nephridium more magnified. No capillaries are represented.

42. Part of cœlomic mantle of one of the posterior nephridia. *se.* secreted matter staining very deep. *n.* nuclei of the glandular cells.

BENHAMIA PAPILLATA.

43A. A specimen, natural size, from Tepic.

43B. The ventral zone of the clitellum.

43C. The same more highly magnified, showing the papillæ and prostate pores.

43D. The two penial setæ in one sack. Zeiss D. Eyep., 2.

43E. The tips of the two penial setæ. Zeiss 12, Eyep., 2, 1.

BENHAMIA PALMICOLA.

44A. The ventral side of the anterior somites.

44B. The ventral region of the clitellum.

44C. A specimen, natural size.

45. Penial setæ. A. apex of the shorter setæ. B. apex of the longer setæ. C. two setæ, whole.

Benhamia nana. Figs. 36 to 42. Benhamia papillata. Fig. 43

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE XLIX.

BENHAMIA PALMICOLA.

46. A somewhat diagrammatic figure, composed from several longitudinal sections. *s. org. pr.* sense organ zone of the prostomium. *s. org. b.* the sense organ zone of the body wall, on the equatorial line of the somite.

47. Some of the sense organ cells of the prostomium more highly magnified. Zeiss. 12; Hom. Im. Eyrp. 2. The sense cells are seen in the center between the pellucid sac-like cells. Between the sense cells are seen nuclei of supporting cells.

48. Part of a posterior somite laid open, showing the three nephridia on one side.

49. A part of a nephridial cell mantle, showing various kinds of cells, some of which appear to contain calculi.

50. Cephalic ganglion, etc.

51. The spermathecal zone seen from the inner side of the body. The large globular apical part of each spermatheca is situated in the somite posterior to the pore.

52. Outlines of the spermathecæ of various extra African species of Benhamia, some of which are copied from various sources.

52A–B–C–D. Spermathecæ of *Benhamia Bolavi*, from specimens from Hamburg, kindly furnished by Dr. W. Michaelsen.

52E. Spermatheca of *Benhamia malayana* after Dr. Horst.

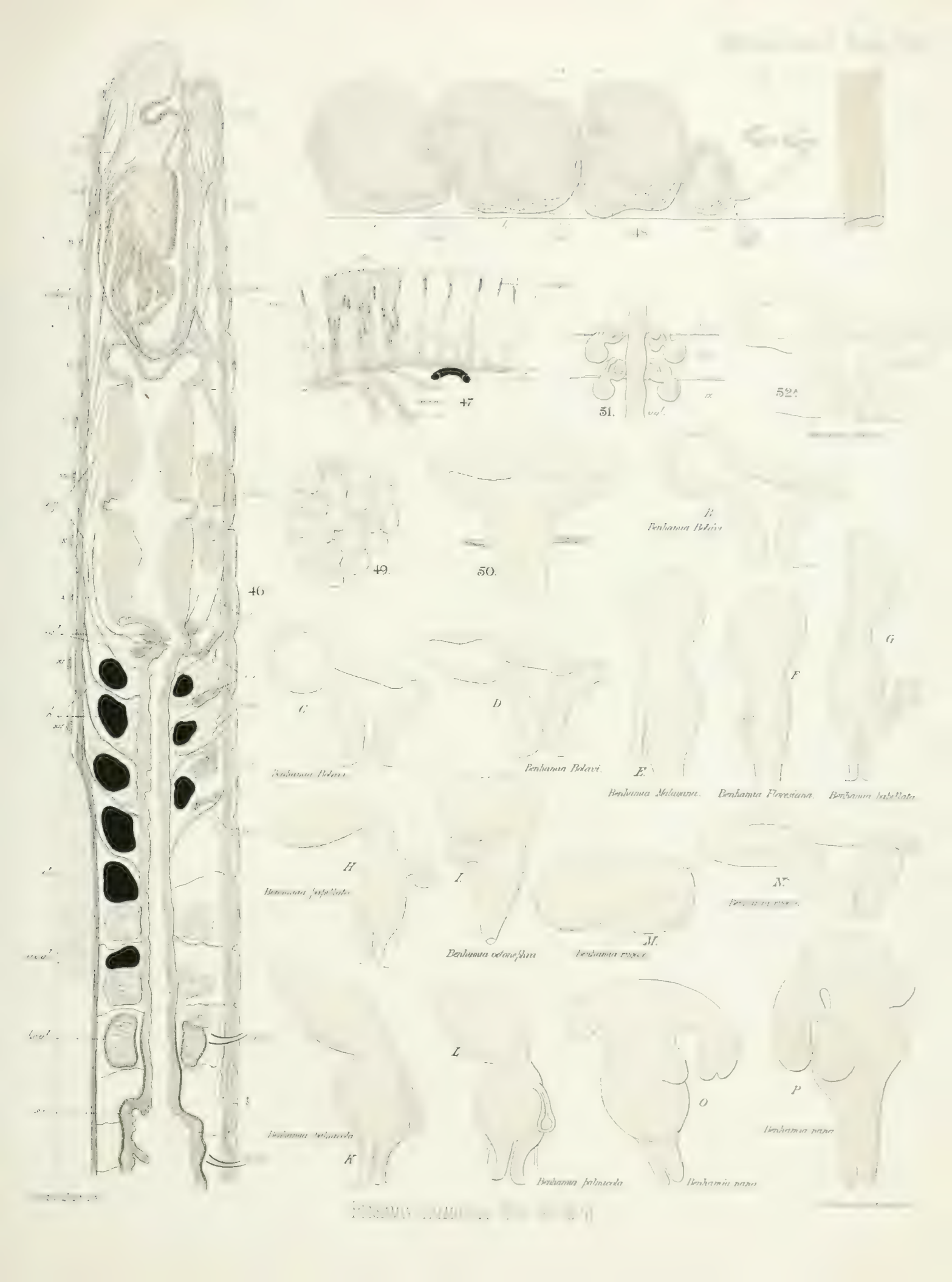
52F. Spermatheca of *Benhamia floresiana* after Dr. Horst.

52G–H. Two spermathecæ from the same side of a specimen of *Benhamia papillata* from Tepic, Mexico.

52I. Spermatheca of *Benhamia octonephra* after Rosa.

52K–L. Spermathecæ of *Benhamia palmicola* from Miraflores, Baja California.

52M–N. A spermatheca of *Benhamia rugosa* seen from two different sides.


46
47
49.
50.
51.
52.
B
Benhamia Bidavi
C
D
Benhamia Bidavi.
E
Benhamia Melanana.
F
Benhamia Florestana.
G
Benhamia labellata
H
I
Benhamia odontophora
M.
L
Benhamia palmarda
K
O
Benhamia nana
P

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE L.

BENHAMIA PALMICOLA.

53. Part of the intestine and hearts dissected out.

54. Prostate and sac with penial setæ.

BENHAMIA RUGOSA.

56. The ventral side of clitellum, showing the copulatory papillæ on which are situated the anterior prostate pores in xvii. The clitellum is much crenulated.

57. Anterior somites seen from above, showing prostomium, somite i, ii and iii, the first of which is much swollen.

58. The same seen from the side. In these two figures somite i is retracted in the buccal cavity.

59. Another specimen; the anterior somites, but i, is fully extended.

60. Larger penial setæ, free end.

61. Smaller penial setæ.

63. A partly diagrammatic representation of the interior surface of a posterior somite, showing the nephridia. 1, 2, 3, 4, small, refer to setæ; 1, 2, 3, 4, large, refer to nephridia.

ALEODRILUS KEYESI.

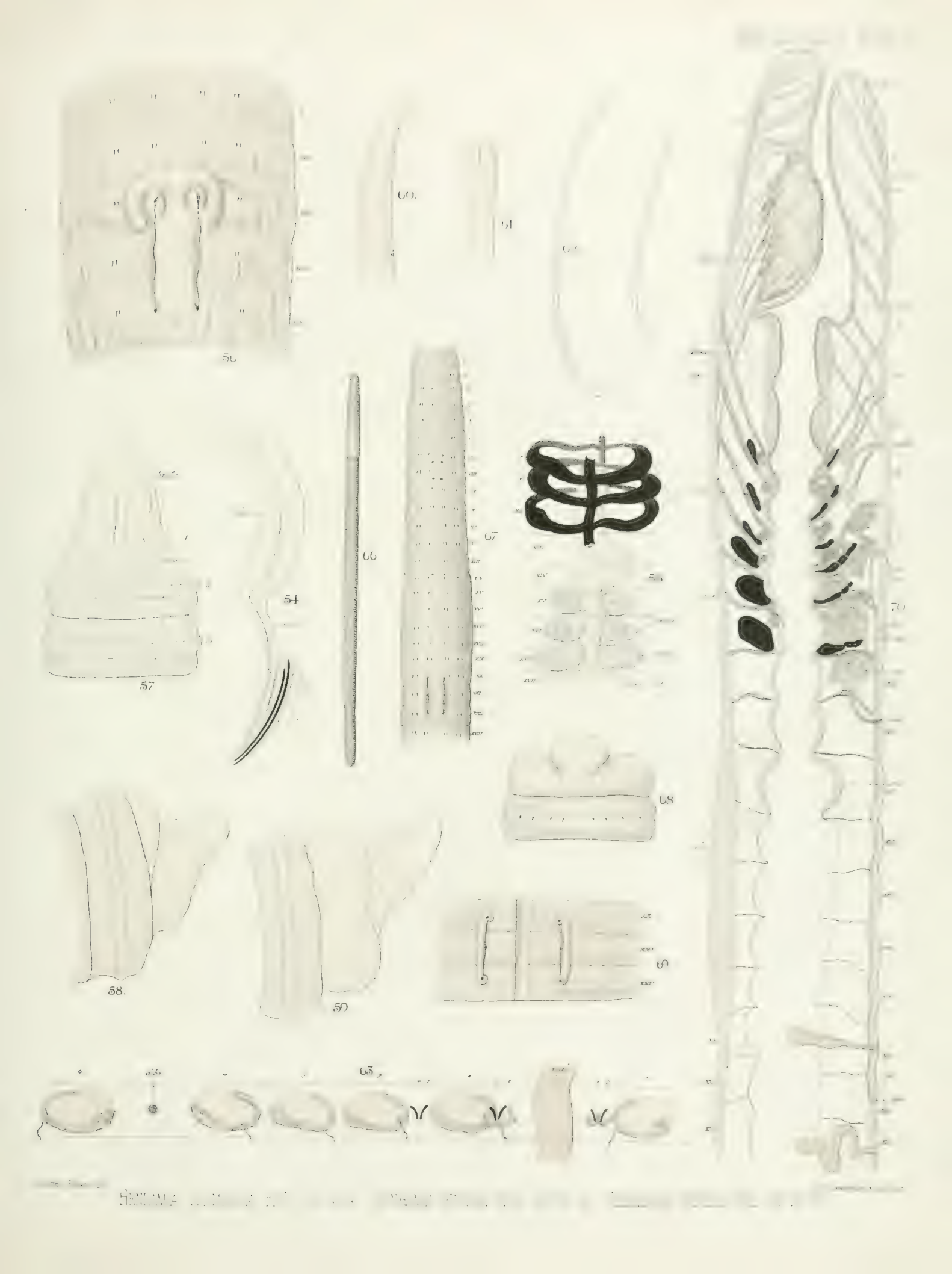
66. A specimen, natural size.

67. The anterior somites seen from the ventral side, showing the generative pores and the position of setæ.

68. Prostomium and somite i.

69. The sexual fossæ and papillæ.

70. A somewhat diagrammatic view of the anterior somites, composed from several longitudinal sections.



REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. ory. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LI.

ALEODRILUS KEYESI.

71. Cross-section through somite ix, showing the septal glands and the thickened septa. *s. gl.* septal gland, the prolongation of which probably connects with the intestine and the median blood vessel. *x.* at this point the ventral vessel and the septal gland have been bent and cut twice.

73. Cross-section through somite xii, showing the posterior sperm-sac. *tra.* trabecula. *v. v.* ventral vessel in two successive somites. *spc.* sperm-cell germinative area of cells with narrow nuclei.

74. Section through apical part of spermatheca.

75. Section through intestine and septal gland in somite x, anterior to fig. 72, showing discharge duct of septal gland. The ventral vessel and heart have been folded and cut three different times; similarly part of the septal gland has been cut twice. *d.* discharge duct of septal gland; it probably reaches in between the epithelial cells of the intestine.

77. Section through dorsal median vessel, where it connects with two lateral vessels; the section goes only through one of the points of connection. The lateral vessels are covered with chloragogen cell.

78. Section through the suspended posterior part of the spermduct in the anterior part of somite xii. The duct is seen suspended between two mesenteric strands, one connecting with the heart, the other with the septum close to the body wall. *h. v.* heart valve. *gl.* gland emptying in spermduct.

79. Section through spermduct in somite xi, the cut going through testis, which is immediately superposed on the duct or rather the posterior part of the ciliated rosette.

80. Section through spermduct going through the ovary in xiii. *a. spd.* spermduct from anterior rosette, already attached to the body wall. *p. spd.* spermduct from posterior rosette, yet suspended and passing through the ovary. *ov.* ovary with full-grown ova, with germ-cells and with a germinative area where cells are in mitosis. The nuclei in the germ-cells are oval, while those in the grown ova are round. Zeiss D. Eyp. 2.

81. Section through spermduct through one of the posterior somites where the two ducts have joined in the body-wall. *clit.* clitellum in xiv.

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellar glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LII.

ALEODRILUS KEYESI.

82. Section through the epithelium of tubular intestine, showing a cluster of glands between the epithelial cells. *bl.* blood lacune.

83. Section through one of the valves of the heart. *l. c.* large cells at the base of the valves.

84. Some spermatogonia from the sperm-sacs in xii.

85. Cells from the central germinative and in the sperm-sac.

86. One of the nephridia with an anterior lateral vessel, connecting dorsally with a branch from the ventral vessel. *d. v.* diverticula of the lateral vessel. *lat. v.* lateral vessel.

ACANTHODRILUS TAMAJUSI.

87. The largest of my specimens, natural size. This specimen is strongly contracted, and was when alive considerably longer.

88. The anterior somites, ventral view.

89. The anterior somites, dorsal view.

90. The anterior somites, side view.

91. The ventral part of the genital region in the clitellum, showing genital papillæ, the three transverse genital ridges, penial setæ, common setæ, etc. The clitellum is not well developed, but in somite xx may be seen its posterior termination. The other one of my specimens, which possessed a more developed clitellum, had these papillæ less pronounced, though of the same form and arrangement.

92. Cross-section of the body-wall, showing the common setæ.

93. The free end of the penial seta.

94. The spermathecæ, dorsal view.

95. One of the spermathecæ dissected out.

ODRILUS KEVESI FIGS 82 TO 95 ACANTHODRILUS

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LIII.

ACANTHODRILUS TAMAJUSI.

96. A somewhat diagrammatic view composed from several longitudinal sections of the body. *r. m.* retractor muscles of gizzard. *c. c.* masses of free cœlomic cells.

SPARGANOPHILUS BENHAMI.

97. Adult specimen, natural size.

98. The anterior somites, ventral view, including clitellum, tubercula pubertatis, etc., magnified four times.

99. Longitudinal section of the anterior somites passing through the spermathecal and prostate pores, composed from several sections. Somites xix–xxii are not figured. *sep. gl.* septal glands which open in the dorsal part of the pharynx. *l. sep. gl.* lower septal glands which open in the ventral part of the pharynx. The spermathecæ have been cut through diagonally and the figure does not give any idea of their real shape.

101. Section of the body-wall in ventral part of somite xii. *p.* peritoneum. *n. ep.* nuclei of supporting cells.

102. Longitudinal section of the clitellum. *1.* Supporting cells. *2.* Unicellular glands. *3.* Short clitellar cells, staining deeply, and furnished with perfect nuclei. *4.* Largest clitellar cells, staining less deeply and with imperfect nuclei. Zeiss D.

103. A part of the same section, more magnified. Iron, hæmatoxylin, Haidenhein, Ehrlich 3 acid. Numerals indicate the same as in fig. 102. *d. n.* degenerate nuclei of the 4 cells. *n. sec.* cell plasma around the nuclei pushed far back in the apical part of the cell. *n. sh. c.* nuclei of the short clitellar cells surrounded by cell plasma and mucin. *c. t.* connective tissue. *bl. c.* blood capillaries which are very scarce in the clitellum of this species.

104. Section of the body wall in somite xiv.

105. Cross-section through clitellum and tubercula pubertatis. *1.* Supporting cells. *2.* Unicellular glands. *3.* Shorter clitellar cells staining darkly. *4.* The longer clitellar cells. *5. tpc.* tubercula pubertatis cells, largest kind. A few of these are seen to contain free but shrunken nuclei. *6. tpc.* tubercula pubertatis cells of the narrow kind, with cell plasma in the apical end, but also with shrunken nuclei. *t. p.* tubercula pubertatis groove. *n. f.* nerve fibers. *cl. c. 2.* large unicellular glands, a large form of the usual unicellular epidermal glands. Above these is seen a wide lumen, probably a blood vessel.

106. Longitudinal section of the body-wall, through spermatheca.

107. Longitudinal section of body-wall through prostate and pore in somite xxiv. *t. c.* tubular supporting cells. *g. c.* glandular cells confined to the zone around the intersegmental grooves.

108. The same as 107, more magnified.

109. The inner whorl of the ciliated rosette.

110. Section through the œsophagus. *i. c.* interstitial cells. *gl.* interstitial glands.

111. Section through intestine in somite xii. *fibr.* blood crystals and fibrine. *w. bl. w.* wall of blood sinus.

112. Section through upper pharyngeal wall, showing epithelial cells, and between them the discharge tubes of the glands. Zeiss 12, hom. im.

113. Section through the same part, showing a three-forked duct.

114. Section through the intestinal wall, next posterior to the real pharynx, showing larger discharge tubes and chambers.

115. Section through ventral wall of pharynx, with ducts and storage chambers of glands, and between them shorter epithelial cells. *m.* and *d.* muscles along which run the ducts. *n. d.* nuclei of ducts.

116. Surface view of one of the larger blood vessels.

117. Outline of one of the nephridia.

118. Outline of a spermatheca.

96.
97
98
99
101
110
111
112

ACANTHODRILUS TAMAJUSI FIG 96 SPARGANOPHILUS BENHAMI FIGS 97 TO 117

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LIV.

SPARGANOPHILUS BENHAMI.

119. Five cross-sections through various parts of the body.

a. Through posterior part of pharynx in somite v. *s. gl.* dorsal septal glands. *l. s. gl.* lower septal glands.

b. Through spermathecæ and somites viii and ix.

c. Through somite x. *t. c. r.* tube of ciliated rosette.

d. Through oviduct, somite xiv with sperm-sacs.

e. Through clitellum in somite xix, showing tubercula pubertatis. *cl. c. 1* long clitellar cells. *cl. c. 2* short clitellar cells. *spd.* spermduct running below the muscular layers.

119A

119C

119B

119D

119E

118A

118B

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. ory. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LV.

SPARGANOPHILUS SMITHI.

120. A large specimen, natural size, ventral view.

121A. Anterior part of the body, side view, showing tubercula pubertatis ridges, and their anterior extension to the center of somite xi. The dorsal and ventral termini of clitellum marked by x.

121B. The anterior somites, ventral view. The spermiducal pore is seen about half way between setæ 1 and 2 and the tubercula pubertatis in xix/xi.

122. Two of the clitellar somites, side view, showing tubercula pubertatis ridge. *v.* ventral. *d.* dorsal side.

SPARGANOPHILUS SONOMÆ.

123. The same as 122, but from *Sparganophilus sonomæ*, showing the tubercula pubertatis ridge to consist of a succession of separate tubercles, two or three on every somite, with the groove very nearly in the center of each papilla.

SPARGANOPHILUS SMITHI.

124. Longitudinal section of the anterior somites, composed from several sections. *v. sgl.* ventral septal glands in v, vi, vii. *s. v.* spermtanks. *s. s.* sperm-sacs. *f.* four large folds of the dorsal vessel in somites xiv–xviii. *sp. gl.* prostates.

125. A series of outline drawings of spermathecæ from one specimen.

SPARGANOPHILUS SONOMÆ.

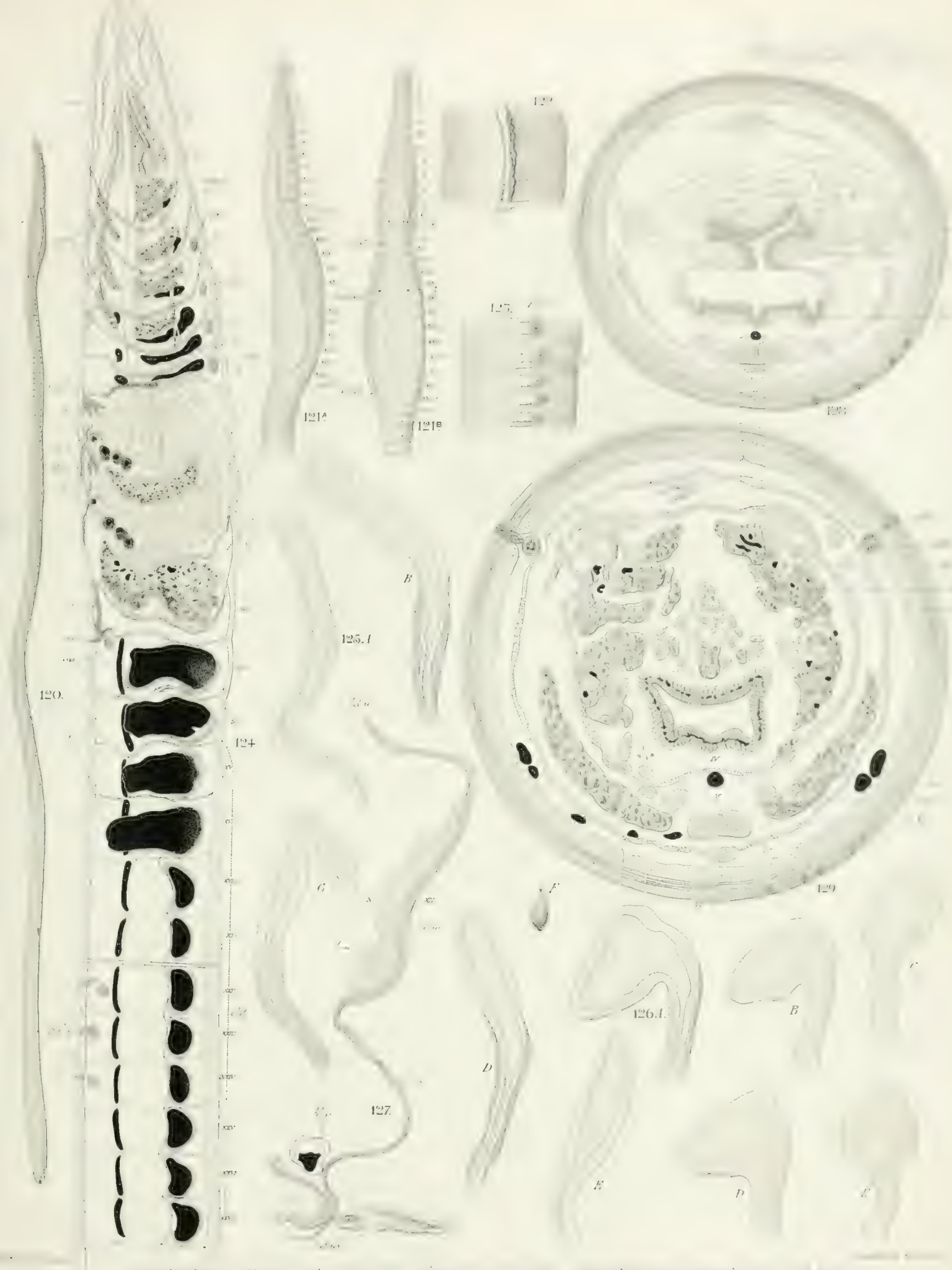
126. Outlines of spermathecæ from a single specimen.

SPARGANOPHILUS SMITHI.

127. Cross-section of septum xi/xii.

128. Cross-section of the body; the Roman numeral indicates the somite.

129. Cross-section of the body; the Roman numerals indicate the somites.


120.
124.
121A
121B
122
123.
125.
126.
126.A
127.
129.
A
B
C
D
E
F
G

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellar glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LVI.

SPARGANOPHILUS SMITHI.

130–136. Cross-sections through various somites. The details are indicated diagrammatically. The Roman numerals indicate the number of the somite or somites through which the section passes. *s. m.* septal muscles. *a. s. gl.* accessory septal gland of septum between somites ix and x. *spz. t.* spermatozoa in spermtanks. *spz. s.* spermatozoa and spermatogonia in sperm-sacs. *os.* ovisac. *a. m. t.* arciform muscles of tubercula pubertatis, connecting the opposite surfaces of the tubercula pubertatis. *a. m. c.* arciform muscles passing from opposite sides of clitellum through the cœlomic cavity.

137. Section through sacculated intestine. *bl. c.* blood capillary reticulum.

138. Tubercula pubertatis, Zeiss Hom. Im. $\frac{1}{12}$. *af. m.* arciform muscles passing through cœlom. *af. t.* arciform muscles confined to the epidermal cells of the tubercula.

139. Section through the body-wall through one of the prostates. *r. m.* retractor muscles passing to the cuticle and the outermost epidermal cells. *ct.* connective tissue.

SPARGANOPHILUS CARNEUS.

140. Two spermathecæ from the same specimens. The free or apical end is seen to be almost globular.

SPARGANOPHILUS GUATEMALENSIS.

141, a and b. Two spermathecæ. The apical end is flat and trawl-like, bearing a sac-like pouch which connects with the interior of the spermatheca, through a small slit.

DELTANIA TROYERI var. CRASSA.

142. A prostate gland with penial setæ.

143. A spermatheca.

DELTANIA TROYERI var. LAGUNÆ.

144. One of the penial setæ with the tip more highly magnified.

145. Two spermathecæ, both from the same specimen. *A* and *B* are seen from the broad side, *C* from the narrow side.

146. Two prostates with penial setæ. A is seen from the flat side, B is seen from the broad side.

147. Section of one of the ovisacs. Zeiss $\frac{1}{12}$, Hom. Im.

141c
141A
141B
142
146B
146A
152
145A
145B
145C

SPARGANOPHILUS SMITHI FIG'S. 130 TO 139 SPARGANOPHILUS CARNEUS FIG 140. SPARGANOPHILUS GUATEMALENSIS FIG. 141. DELTANIA TROYERI VAR. CRASSA FIG'S. 142 & 143. DELTANIA TROYERI VAR. LAGUNÆ FIGS. 144 TO 147

REFERENCE TO LETTERS ON PLATES.

a. c. gl. anterior calcic gland.
a. f. anterior fold of nephridium.
a. nephr. anterior nephridia.
a. spd. anterior spermduct.
atr. atrium.
bd. body-wall.
bl. blood vessel or capillaries.
bl. s. blood sinus.
br. bridge in nephridium.
buc. buccal cavity.
c. clusters of lunate cells.
c. c. columnar cells.
c. ep. cœlomic epithelium.
c. gl. calciferous glands.
ch. discharge chambers of glands.
chlo. chloragogen cells.
cil. ciliated epithelium.
cl. c. clitellar cells.
cl. clitellum.
c. m. circular muscles.
com. commissures.
c. r. ciliated rosettes or sperm-funnels.
c. t. connective tissue.
cu. cuticle.
d. gl. dark staining glands.
d. pr. dorsal pore.
d. v. dorsal vessel.
e. epithelial cells.
ept. epithelium.
gl. glands.
gl. c. unicellar glands.
gl. pr. glandular part of prostate.
gizz. gizzard.
h. heart.
hy. hypodermis.
i. s. gr. intersegmental groove.
l. c. large cells.
l. m. longitudinal muscles.
m. muscles.
m. atr. muscular atrium.
mes. mesenteric tissue.
m. pr. muscular prostate.
n. nephridia.
n. c. nerve cells.
ne. nerve ganglion.
nec. neck of nephridium.
neph. nephridium.
neph. p. nephropore.
œs. œsophagus.
ov. ovary.
ovd. oviduct.
org. sense organ.
p. c. gl. posterior calciferous diverticulum.
p. f. posterior fold, nephridium.
phx. pharynx.
p. neph. posterior nephridia.
pr. prostate.
p. spd. posterior spermduct.
pr. sto. prostomium.
ps. penial setæ.
prt. peritoneum.
se. secreted matter.
s. int. sacculated intestine.
sep. gl. septal gland.
sep. septum.
s. gl. suprapharyngeal glands.
s. org. b. sense organ cells in equatoreal zone.
s. org. pr. sense organ cells in prostomium.
spc. sperm-cells.
spd. spermduct.
spgn. spermatogonia.
spr. spur of nephridium.
s. ps. sac with penial setæ.
sp. s. sperm-sacs.
s. ph. sgl. subpharyngeal glands.
spth. spermatheca.
spth. p. spermathecal pore.
t. testes.
t. m. transverse muscles.
trb. trabecula.
th. spd. thicker part of spermduct.
tu. tubular intestine.
tub. p. tubercula pubertatis.
ty. typhlosole.
u. c. unicellular glands.
v. g. ventral ganglion.
v. v. ventral vessel.
v. sgl. ventral gland.
w. "windings" of nephridial ducts.

PLATE LVII.

ACANTHODRILUS VASLITI.

148. The largest specimen, natural size, but not yet adult; the clitellum not developed.

149. Anterior part of a young specimen; clitellum not developed. The nephridia and some other detail not figured. *s. pl. sgl.* subpharyngeal salivary gland. *prc. ss.* peritoneal cells forming solid masses, probably surrounding rudimentary sperm-sacs. *prc.* large peritoneal cells lining the septa as well as the peritoneum. *a. p. pr.* anterior pair of prostates opening close together. *p. p. pr.* posterior pair of prostates.

150. Part of the ventral part of the body in somites xvii, xviii, xix laid open, showing prostates and thick septa with peritoneal cells. *m.* copulatory muscles. *a. pr.* anterior prostate. *p. pr.* posterior prostate both of the same pair.

151. Cross-section of the body-wall in somite xix, showing the prostate pore, and the two prostates opening close together.

152. Section through the same pore, three or four sections further back, showing the tubercula pubertatis, sense organ, etc. *deb.* debris. *sup. c.* supporting cells.

153. Part of a septum, showing the very large peritoneal cells, some of which are broader, others longer and narrower.

154. Cross-section of the two prostates. *p. pr.* posterior prostate pore. *a. pr.* anterior prostate pore. *prt.* peritoneal cells and connective tissue connecting the prostates with the body wall.

PHŒNICODRILUS TEPICENSIS.

155. Spermathecæ, side and front view of one and the same.

156. Cross-section of the body in somite xvii through the male pore, showing the copulatory region with muscular atrium and spermduct. The longitudinal muscular layer is greatly increased at the male pore. The muscular atrium is seen in cross-section, the cut passing through the whole length of that organ. This is also seen in figures 158, 159, the latter being taken from a section posterior to the former.

157. The oviduct, ovisac and part of the ovaries, interior view of the body.

158. Section through muscular atrium in cross-section of the body. The spermducts have not yet united, nor have they entered the atrium. The section passes through the whole length of the atrium. The arciform muscles must have been torn, as they did not show in the section.

159. The same parts as seen in fig. 158, but four sections further back, the section passes through the outer layers of the atrium. The two spermducts have united and are entering the atrium in line with the longitudinal muscular layer.

160. Arciform muscles around one of the male pores, viewed from the interior surface of the body. Only one side is shown.

149.
150
154
152.
151
148.
155B
155A
156
155A
153
157
155B
160
159.

Volume II.

Index of Scientific Names.

New names in **heavy-faced** type.

Acanthodrilidæ 144, 145, 146, 166
Acanthodrilus 45, 131, 139, 142
georgianus 45
tamajusi 123, 139, 140
Vasliti 123, 129, 139, 142, 144, 145, 172
Aleodrilus 145, 146, 149
Keyesi 123, 146, 169
Allolobophora 41, 128, 164
Argilophilus 21, 29, 41, 44, 45, 47, 48, 49, 53, 55, 56, 65, 68, 70, 81, 130, 148, 167
marmoratus 164
ornatus 44, 53
papillifer 44, 55

Benhamia 124, 125, 128, 129, 130, 131, 134, 138, 139, 145, 146, 147, 148, 164
Annæ 123
Bolavi 123, 124, 125, 129, 132, 134, 135, 136, 138
floresiana 123
Godeffroyi 123, 126
kafuruensis 137
malayana 123, 129
mexicana 123, 124, 125
nana 123, 125, 127, 131, 132, 133, 134, 138
octonephra 123, 124, 126, 139
palmicola 123, 124, 125, 129, 131, 132, 133, 134, 135, 136, 138
papillata 123, 126, 135, 136
rugosa 123, 124, 126, 131, 134, 136, 138, 139
Stuhlmanni 134
Bombyx 149

Cryptodrilidæ 21, 166

Deltania 21, 22, 23, 24, 40, 42, 43, 48, 52, 68, 81, 146
Benhami 22, 32, 34, 35, 36, 37, 38, 39, 40
dubia 22, 24, 36, 40
elegans 22, 23, 24, 25, 29, 32, 33, 34, 35, 36, 37, 39, 40, 146
Poultoni 22, 24, 40
Troyeri 22, 28, 31, 32, 33, 34, 37, 38, 39, 40, 170, 171
var. **crassa** 123, 169
lagunæ 123, 170, 171
Diplocardia 146
communis 145

Eclipidrilidæ 84
Eclipidrilus 4, 89
frigidus 84
Eminiodrilus 130
Enchytræus 33, 49, 79, 129, 142, 168
Eudrilidæ 21, 44
Eudrilus 21, 45
dubius 23, 24

Geodrilus singularis 142, 144, 145
Gordiodrilus 63, 173

Hæmagregarina 86
Heliodrilus 45
Hyperiodrilus 45

Kerria 63, 65, 68, 69, 70, 144
McDonaldi 70, 142

Limicolæ 89
Limnodrilus 146
Lumbriculidæ 1, 4, 84, 85, 89
Lumbriculina 1, 3
Lumbriculus 1, 6, 89
Lumbricus 27, 33, 47, 48, 79, 81, 82, 128, 158, 163, 164
agricola 128

Microchæta 32
Microscolecini 21
Microscolex 21, 22, 23, 24
algeriensis 22, 23
dubius 23, 40
modestus 22, 23
novæ-zelandiæ 23
Poultoni 23, 24, 40
Moniligaster 65, 84, 89
indicus 43

Nannodrilus 171

Ocnerodrilidæ 81
Ocnerodrilus 5, 28, 63, 64, 66, 67, 68, 69, 70, 71, 72, 78, 81, 129, 171, 172, 173, 174
Beddardi 30, 67, 70, 72, 172
Hendriei 72
occidentalis 5, 32, 72
Oligochæta 1, 45, 47, 65, 67, 68, 72, 82, 84, 86
Oligochætæ 76, 77

Perichæta 54, 142
Phœnicodrilus 63, 68, 70, 72, 78, 81, 129, 171, 172, 173
taste 64, 66, 69, 71, 72, 123, 171, 172, 173, 174
tepicensis 123, 171, 172

Photodrilus 21, 22, 73, 82, 83
Phræatothrix 4
Plutellini 21, 56
Plutellus 21, 45, 48, 55, 56
Pontodrilini 21
Pontodrilus 21, 22, 66, 68, 70, 73, 78, 79, 83, 86, 129, 150, 167
arenæ 83
hesperidum 76, 81, 83
insularis 83
littoralis 82, 83
Marionis 73, 83, 84
Michaelseni 73, 78, 82, 83, 84
phosphoreus 83
Pontoscolex 157
corethrurus 45

Rhododrilus 21, 23
minutus 22
novæ-zelandiæ 22
Rhynchelmis 2, 4, 5, 6, 7, 164
limosella 2, 3, 4

Sparganophilus 136, 151, 152, 153, 154, 155, 157, 158, 162, 163, 166, 167, 168
Benhami 123, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 165, 166, 167, 168, 169
carneus 123, 151, 153, 155, 168
Eiseni 123, 151, 152, 153, 154, 156, 158, 159, 166, 167, 169
guatemalensis 123, 151, 153, 155, 161, 166, 167, 168, 169
Smithi 123, 129, 151, 152, 153, 154, 155, 156, 158, 159, 160, 162, 165, 166, 167
sonomæ 123, 151, 153, 154, 156, 159, 160
tamesis 123, 151, 153, 156, 157, 158, 159, 162, 163, 165, 166
tepicensis 129
Sutroa 2, 3, 4, 5, 6, 89, 168
rostrata 2, 3

Telmatodrilus Vejdovskyi 90
Tericolæ 89
Trichodrilina 1
Tubifex 89

Q
11
C17
v.1-2

California Academy of Sciences,
San Francisco
Memiors
v.1-2

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

STORAGE